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Commercial Practices as Applied to Total Asset Visibility

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FOR THE COMMANDER

//SIGNED//

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14. ABSTRACT
This document provides an overview of the military's objective for their Joint Total Asset Visibility (JTAV) 2020 program. In addition, this document reviews the current supply chain of the Air Force and attempts to identify areas of improvement and makes recommendations as to how specific areas of the supply chain might be enhanced through current commercial practices and technology regarding asset visibility. Extensive research has been reported in the fields of Automatic Identification (Auto-ID) and Radio Frequency Identification (RFID) along with other current commercial practices and technology involving asset visibility. RFID combined with an effective database system will give the Air Force complete visibility into its supply chain. The Air Force will have the ability to locate materiel anywhere in the world in real time. It is recommended that the Air Force adopt RFID tags and readers throughout the supply chain that interface with the database system described above.

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EXECUTIVE SUMMARY

"Asset blindness" occurred in Operations Desert Shield and Desert Storm. Over the course of these two conflicts, over 40,000 military containers were shipped to the Middle East. More than 20,000 of these containers had to be opened, inventoried, resealed, and reinserted into the transportation system, because military personnel on the receiving end did not know the contents of the containers or their final consignees. At the conclusion of the conflict, there were more than 8,000 containers and 250,000 Air Force pallets that were unopened and their contents still a mystery.

General Robert H. Scales, in his book, *Certain Victory: The U.S. Army in the Gulf War*, details many of the logistical deficiencies realized by the U.S. military during the "build-up" of forces for Operation Desert Shield. Early in the conflict, tracking the location of shipping contents and determining their contents was a major problem as materiel flowed from U.S. warehouses to the Persian Gulf. General H. Norman Schwarzkopf made the decision in the early stages of the operation to focus on the arrival of combat personnel and equipment rather than logistics personnel. This decision created an expected deficiency in the supply chain of the military. Many of the shipping containers were labeled with only the bare minimum of information that transportation regulations allowed due to the lack of personnel to properly document the contents of the containers.

Joint Total Asset Visibility is currently deployed in the U.S. Joint Forces Command, the U.S. Pacific Command, the U.S. European Command, the U.S. Central Command, and the U.S. Forces Korea. Joint Total Asset Visibility is the ability to provide users with timely and accurate information on the location, movement, status, and identity of units, personnel, equipment, and supplies. JTAV also seeks to utilize the aforementioned information to improve the Department of Defense's logistic practices. JTAV, in its current state, is not yet "total." Parts of the JTAV concept are three asset categories: "in storage," "in transit," and "in process." These categories help JTAV to determine the "location, movement, status, identity of units, personnel, equipment, and supplies." These categories are the broad divisions that make up the JTAV supply chain.

The main focus of JTAV is an integrated data environment. The concept of JTAV must collect data from the various databases that store information on the three types of assets listed above. This information must then be processed such that all of the data is merged into a form that is easy to understand for the user. The primary challenge in accomplishing this task is the tremendous number of databases that exist and attempting to link all of them together. Each of the databases represents a small portion of visibility for a particular category, function, or agency within the DOD. Joint Vision 2010 attempts to create a system architecture that allows a "single point of entry" into the many dimensions of TAV.

This document provides an overview of the military's objective for their Joint Total Asset Visibility (JTAV) 2020 program. In addition, this paper reviews the current supply chain of the Air Force and attempts to identify areas of improvement and makes recommendations as to how specific areas of the supply chain might be enhanced through current commercial practices and technology regarding asset visibility. Extensive research has been reported in the fields of Automatic Identification (Auto-ID) and Radio Frequency Identification (RFID) along with other

current commercial practices and technology involving asset visibility. RFID combined with an effective database system will give the Air Force complete visibility into its supply chain. The Air Force will have the ability to locate materiel anywhere in the world in real time. It is recommended that the Air Force adopt RFID tags and readers throughout the supply chain that interface with the database system described above.

In order for RFID to be implemented all materiel must be tagged. This is best accomplished by the manufacturer, in the production stage, so that the tag is internal and protected from damage and tampering. The Air Force will need to embark upon a program that gets manufacturers of Air Force products to tag their parts and products in the manufacturing stage. This will be a difficult task since tagging parts will require retooling, and in some cases require redesigning the part itself. All parts of assemblies and aggregates must be tagged. For example, if Lockheed Martin delivers an F-16 to the Air Force, every part of the F-16 must be tagged. This, of course, only needs to be done with parts that need to be explicitly tracked. It is not necessary to tag bolts, screws, washers, etc.

The Air Force should begin its tagging program at the pallet or container level and work down from there to case tagging and eventually item tagging. Item tagging will offer the most benefit to the Air Force, but of course is the most difficult to implement. Implementation of tagging in phases will allow the Air Force to gradually adjust to automatic identification and RFID technology. This will also greatly reduce the number of readers that initially need to be installed in the Air Force supply chain infrastructure.

Readers will have to be distributed throughout the Air Force supply chain and anywhere tags will need to be read. Readers will need to be installed at all warehouse and depot areas. For the monitoring of aircraft, readers should also be placed on the flight line for spot-level locating of specific aircraft.

The two main choices in RFID are whether to implement active or passive technology and what frequency(s) to select. Due to the high variability of environments and conditions in which RFID tags will be read, it is recommended that the Air Force use multi-band readers. The Air Force has assets on the water, in the desert, in the air, and in warehouses. These environments will necessitate a versatile reader capable of operating in all of these environments. Following the recommendations of the Auto-ID center, the reader should have capabilities of reading both high frequency (HF) (13.56 MHz) and ultra high frequency (UFH) (915 MHz) frequency bands. Each band will provide benefits for specific applications and it important to have the versatility to switch between the two. High frequency bands are less expensive than inductive low frequency tags and are generally passive in nature. They have a short read range and are best suited for applications that do not require multiple tag reads. This is also currently the most widely available frequency world wide.

Ultra high frequency tags, when purchased in high volumes as the Air Force would, can be cost effective over LF and even HF tags. Their high performance and range are well-suited for multiple tag reading applications. This frequency is for use with active tags or passive tags, but the performance comes with active tag applications. The draw back to this frequency is that Japan does not allow this transmission on this band.

Both active and passive technologies have their place within the Air Force supply chain. Specific instances of when active and passive RFID should be used are detailed above; an overview is given below. Active RFID should be implemented for the most part, but there are specific areas where passive RFID may be used to reduce cost. Active RFID should be used for area monitoring applications such as obtaining real-time inventory information in a warehouse, monitoring the location of empty and loaded air cargo containers, and monitoring the security of stored containers. RFID should also be used in spot-level locating applications such as determining the exact parking location of aircraft, locating the specific storage rack of a pallet or container within a distribution center, or identifying the specific loading bay in current use.

Passive RFID should be used for locating specific objects in a small area such that the surrounding areas are not also scanned. Passive RFID operating at 13.56 MHz would work best, also eliminating unwanted "cross reads" that can occur with higher frequencies. Anytime multiple tags need to be read such as multiple pallets, containers, or objects moving through a port, active RFID should be used. Whenever security or tampering is an issue for materiel located within a container, Active RFID should be implemented to create electronic seals. Passive RFID can be used on low-level security items where it is only necessary to determine if a container has been opened or not, and no further information is necessary.

For higher-level security items, active RFID should be used to log the time that the seal was tampered with. Active RFID also offers sophisticated "anti-spoofing" technology to prevent the tag from being tricked. Electronic manifests will be very important in deployment situations. As mentioned above, a huge problem in Operation Desert Storm was the lack of visibility into Air Force containers. With an electronic manifest detailing every element of materiel inside, the contents can automatically be updated and checked into a database. Only active RFID offers electronic manifest capabilities built into the tag. As mentioned earlier passive tags are capable of pointing to an electronic manifest located on an external database.

Constraints exist when using radio frequency technology in the presence of munitions. For this reason it is recommended that global positioning satellite (GPS) tags be used to track munitions. Not only does this eliminate radio waves around explosive ordinates, it also provides constant, real-time tracking of munitions anywhere in the world. This is especially useful given the importance of extra security precautions needed in storing and transporting munitions.

Wal-Mart is always on the forefront of emerging technology, and due to its dominating position in the market, has the ability to enforce any implementations it wishes to impose. In June of 2003 Wal-Mart set the date of January 2005 for RFID implementation (Murphy and Hayes 2003). This means that 100 key suppliers will have to work with Wal-Mart using RFID to track pallets of goods throughout its supply chain. With this deadline in place there are still many issues to consider, primarily the shortcomings of the current technology and the cost of purchasing RFID tags and readers.

Linda Dillman, Wal-Mart's CIO outlined a timeline for RFID implementation. This quarter the scope of the pallet initiative will be defined, with detailed specifications emerging in the third and fourth quarter of 2003. RFID will then be tested through 2004 and go online with 100 of its

largest suppliers in 2005. Dillman states that "At some point, like any other technology, like EDI, [RFID will] be a requirement for doing business with Wal-Mart." The Air Force, like Wal-Mart has the force in the market place to make these kinds of demands on its suppliers.

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Milestone A – Preliminary Investigations

1 Introduction

"Asset blindness" occurred in Operations Desert Shield and Desert Storm. Over the course of these two conflicts, over 40,000 military containers were shipped to the Middle East. More than 20,000 of these containers had to be opened, inventoried, resealed, and reinserted into the transportation system, because military personnel on the receiving end did not know the contents of the containers or their final consignees. At the conclusion of the conflict, there were more than 8,000 containers and 250,000 Air Force pallets that were unopened and their contents still a mystery (Taylor 2001).

"It's all about total asset visibility," says John Coburn, retired four-star commanding general of the United States Army, materiel command, an operation that supports the Army in all aspects of logistics. "If you manage an operation, at all times, you need to know what you have," he says. During the Gulf War, the Army didn't know the contents of about 40,000 containers. "I personally opened containers just to see what was inside. Over the years we had this problem of not having total asset visibility (Hyland 2002)."

General Robert H. Scales, in his book, *Certain Victory: The U.S. Army in the Gulf War*, details many of the logistical deficiencies realized by the U.S. military during the "build-up" of forces for Operation Desert Shield. Early in the conflict, tracking the location of shipping contents and determining their contents was a major problem as materiel flowed from U.S. warehouses to the Persian Gulf. General H. Norman Schwarzkopf made the decision in the early stages of the operation to focus on the arrival of combat personnel and equipment rather than logistics personnel. This decision created an expected deficiency in the supply chain of the military. Many of the shipping containers were labeled with only the bare minimum of information that transportation regulations allowed due to the lack of personnel to properly document the contents of the containers.

According to General Scales, "Because the personnel needed to document the receipt of material were not among the early arriving units, stacks of containers sat in ports unprocessed, their exact contents unknown." Locating a specific high priority item for expedition was extremely difficult indeed. Containers shipped by air also experienced these problems; despite tail number identifications many air shipments were lost (Beatty 2002).

Many of these problems have been handled to some degree, such as the addition of a paper manifest with shipping containers that detail their contents. However, these manifests are often inaccurate or incomplete. Problems of the past have caused some personnel to lose faith in the logistics system, often submitting numerous requisitions for the same item and abusing the priority system process. This has caused the transportation system to overflow with superfluous materiel. With today's technology there is a plethora of means to make this process much more efficient and "visible." With RFID and automatic identification technology the military will not be as dependent on supply personnel.

2 Joint Total Asset Visibility (JTAV)

Joint Total Asset Visibility is currently deployed in the U.S. Joint Forces Command, the U.S. Pacific Command, the U.S. European Command, the U.S. Central Command, and the U.S. Forces Korea.

"Joint Total Asset Visibility is the ability to provide users with timely and accurate information on the location, movement, status, and identity of units, personnel, equipment, and supplies." JTAV also seeks to utilize the aforementioned information to improve the Department of Defense's logistic practices. JTAV, in its current state, is not yet "total."

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2.1 Current Architecture

Several automated systems are currently in place that supplies TAV information to the common JTAV Web-based entry:

Global Combat Support System (GCSS)
The GCSS is the foundation of JTAV which links all of the information from various DOD databases to a single web-based hub. DOD automated logistics systems will update this web-based hub with TAV updates that may be accessed by authorized users.

Inventory control point (ICP) automated information systems
ICP commodity managers use these automated information systems to determine inventory levels. The risk of carrying excess inventory is minimized with a common database through which information is retrieved. Managers will be able to effectively utilize on-hand inventory through visibility, rather than procuring outside inventory to fill requests when the inventory is available on-hand.

The ICP automated information systems provide the following visibility:

- On-hand wholesale and retail assets by location and condition code.
- Wholesale assets due in from procurement and their projected delivery dates
- Items in intermediate- and depot-level repair, with projected repair completion dates.
- Requisitioning objectives and retention limits for every reporting supply activity.

Global Transportation Network (GTN)
The GTN provides in-transit visibility of material in the Defense Transportation System. The GTN is a web-based system located on a secure server that provides visibility of units, personnel, equipment, and supplies as they move through various nodes of the transportations network. Visibility is not maintained between nodes. GTN also interfaces with the automated in-transit visibility systems of commercial carriers.

Defense Standard System (DSS) DSS is yet another automated system that supplies TAV data to JTAV. It provides visibility on material moving through distribution depots and transmits this information to the GTN

Transportation Coordinator's Automated Information Movement System II (TC-AIMS II)
TC-AIMS II, another automated system, will eventually provide transportation and movement information to all of the armed services in a joint venture. This system is currently still in the development stages and will eventually replace the Transportation Coordinator Automated Command and Control Information System (TC-ACCIS) and the Department of the Army Movement Management System (DAMMS).

Movement Tracking System (MTS) The MTS provides near real-time visibility of material moving through the supply chain in an operations setting. Under this system, material may be redirected to alternate locations without drivers having to return to their home bases for alternate instructions (Anderson 2001).

The current system architecture that is deployed to the unified commands is referred to as JTAV-In Theatre (JTAV-IT). The current architecture is moving from a more archaic client-server based technology to a much more versatile platform as the World Wide Web.

The current JTAV system operates as follows. A centrally located server receives data transmissions from a number of "authoritative" sources such as the ones listed above. Data transmissions arrive to the server at regular intervals (providing near-real time data) via the standard file transfer protocol (FTP). The data may be either pushed by the authoritative source, or pulled by the server in order to initiate the data transmission.

A user may access the JTAV application via the web. He/She will be required to submit a user ID and password. Upon authentication the user will select from one of the following functional areas: inventory, ammunition, war reserve, transportation, medical, etc. to start a search. The application will return the results in a few seconds. If a user were to input a particular National Stock Number (NSN) into the application, within seconds a list of location and quantity of the particular NSN would be returned for each of the inventories of the branches of service. If only one branch is desired, the others may be deselected.

One caveat to this system is that the system is only as accurate as the authoritative source. If the authoritative sources are not kept accurate and up to date, the system will only be as strong as its weakest link. In addition, the database is not updated in real-time, but at various intervals or "near" real-time.

2.2 Objective Architecture

The objective architecture of JTAV currently under development seeks to eliminate the push/pull FTP data requests under the current system. It takes advantage of middleware technology; the middleware will query the authoritative sources directly and merge the data before returning the data to the user. This will eliminate the periodic updating of the JTAV system by the authoritative sources; therefore the user will be able to obtain real-time data from the authoritative sources. Just like the current architecture, the objective architecture uses NIPRNET for unclassified communications and SIPRNET for classified communications (Taylor 2001).

The following outlines the objective system process from Taylor (2001)

- A data dictionary defines all potential data in the environment
- The directory identifies where the data reside (which of hundreds of authoritative sources) and explains how to translate the data in the view defined by the dictionary;
- The dictionary and directory are installed in the middleware; and,
- The latter uses the directory to submit requests to the data source and present the data to the user

3 Current Air Force Supply Chain

The current Air Force supply chain differs tremendously from the goals of JTAV 2020 and even the supposed early implementations. Based on the trip to Hill Air Force base (AFB) and interviews with personnel concerning the supply chain at other Air Force bases, it seems that the current level of supply chain visibility is very low.

The following summary of the current Air Force supply chain is based on observations and interviews with personnel at Hill AFB. The Air Force supply chain presented here is independent of published papers and attempts to present how the supply chain actually operates on an Air Force base.

3.1 Actual Supply Chain Operation Observed at Hill AFB

3.1.1 Supply Databases

Once aircraft maintenance personnel determine a particular part is needed, a phone call is typically made to maintenance supply. Supply will then check a series of databases. There are a multitude of databases that may be accessed to determine whether a part is available. Some of the databases are more reliable than others, and there is a lot of overlap. Supply personnel often must check several databases in order to determine whether a part is available or not.

The Core Automated Maintenance System (CAMS) will tell the user if the part is in the warehouse on the base. CAMS was recently upgraded to a more user-friendly graphical user interface from an older green, text-based interface. The Standard Base Supply System (SBSS) is a text-based database that contains supply information on the base as well as other bases. SBSS also contains information on almost every conceivable kind of part such as the part name, part number, cost, size, weight, etc. Information contained in SBSS is often not very reliable as the database is only updated once every quarter.

WebCats, part of the Defense Logistics Agency (DLA), is a web-based database that tells if any part is located within a DLA warehouse. This database is updated every 24 hours. Assets are tracked manually in this system; parts leaving the warehouse are manually keyed into the computer. No advanced technologies (barcodes, etc.) are implemented.

The Stock Control System (SCS) is another web-based database, but is not believed to be very accurate and personnel must often call to verify the availability of parts listed in the database. Windows Mission Capable Asset Sourcing System (WinMASS) contains a graphical user interface that allows personnel to check if other bases have a particular part on their shelves. A phone call must then be placed to the other base in order to receive the part.

Air Force supply personnel also have the option to obtain parts from the "boneyard" at Davis-Monthan AFB, AZ as a last resort. There is no database for parts contained in the scrap yard, supply must call and place a request. The part will either show up a few weeks later or not. There is no further notification or transaction communication that takes place. If a part does arrive, there is no guarantee as to the condition or functionality of the part.

One can look to see what is available locally (on the base) through CAMS but cannot see worldwide. Only the Regional Supply Squadron (RSS) located in Langley, Virginia has worldwide visibility capability. RSS has no web-based access; personnel must e-mail or call via telephone RSS and speak with a person at RSS in Langley who will then search the database for available parts.

If the Air Force does not have the part within its system, the manufacturer will be contacted. Sometimes parts are no longer being produced and a third party must be hired to retool their plant for a particular part. This obviously is very expense and puts a tremendous strain on the supply chain. Gone are the days of depot warehouses full of parts. With budget cutbacks, the government has attempted to move to a just-in-time (JIT) policy. Unfortunately due to severe deficiencies in the supply chain, there is often a tremendous delay in the arrival of parts.

3.1.2 Shipping

Commercial shippers such as Federal Express and the United Parcel Service (UPS) are used almost exclusively for shipping parts from base to base, from manufacturers to bases, and from regional supply centers to bases. Visibility and tracking are available only through the consumer tracking that Federal Express, UPS, and other commercial carriers provide. If Air Force personnel want to see if a part has been shipped, they would have to look it up on the Internet as

any civilian consumer would track a package. The tracking numbers are usually obtained by calling the source of the part on the telephone and speaking to someone who would look up the tracking number. E-mail is also utilized, but used less often due to lack of response and the advantage of real-time information via the telephone. Tracking numbers may also be obtained from the SBSS and a few of the other web-based databases. Access to SBSS information is limited to computers with privileges to the SBSS network; it is not a web-based system.

3.1.3 Central Receiving

Parts arrive at the base through central receiving, which has been contracted out to E G & G. E G & G is a leading provider of technical services to agencies of the U.S. Government and commercial business. Services include management, engineering, scientific, technical, facility operations and logistics support (www.egginc.com 2003). Maintenance supply personnel say parts are often lost at this stage of the supply chain. Parts are often signed for and then set aside in the warehouse until a further request is made for the package; no attempt is made to notify the recipient of the package of its arrival. Air Force personnel often go to central receiving to help out and train contracted personnel in an effort to ensure parts are not lost and are in fact received by maintenance personnel who badly need them. Receiving is negatively termed the "black hole" on base.

On average it takes three days for maintenance personnel to receive a part once central receiving obtains it (if a part was sent overnight via Federal Express, it would still take an additional three days for maintenance personnel to get their hands on it). This outsourcing phenomenon is common at most Air Force bases where contractors mainly handle distribution depots. Maintenance supply personnel say parts often just sit on the floor of the depot once they have been signed for, and it is often unknown whom the part is for, due to deficient addressing/labeling practices. Maintenance supply must often personally check Federal Express web sites to see if the part has been delivered, and then go to the depot and pick it up themselves.

3.1.4 Standard Asset Tracking System

The Standard Asset Tracking System (SATS) is the next generation of Air Force visibility which uses bar codes to track assets. SATS is a frond-end user interface for SBSS. It is not currently implemented at Hill AFB although several bases are currently using beta versions.

Pete Longworthy of the Northrop Grumman Information Technology office in Williamsburg, VA was interviewed to obtain detailed information on the Standard Asset Tracking System (SATS) not found in the Air Force supply manual (AFM 23-110). Mr. Longworthy played a role in the development of SATS at Northrop Grumman.

SATS was developed in the late-1990s in order to eliminate the paper environment of the Air Force supply chain through automatic identification technology (AIT). SATS serves as a front-end to the Air Force's Standard Base Supply System (SBSS); it is the Air Force's attempt to apply the commercial practices of barcodes into their existing infrastructure. SATS is designed to serve receiving, putaways, pulling, and movement throughout a warehouse. It provides the ability to monitor who received a particular item and store the location of the item within the

warehouse. Currently about 60% of Air Force bases currently have SATS. It is important to note that SATS only provides increased visibility at the base level but does not provided visibility between bases.

SATS consists primarily of barcodes, radio frequency transmitters, and smartcards. A SATS-ID (in barcode form) is generated for every transaction. Data is captured from these Department of Defense (DoD) standard 1348-1A barcodes that are scanned by wireless handheld barcode scanners that transmit the data via radio frequency to transmitters that are located throughout a warehouse. These transmitters relay the information to the database. The barcode is contained on printer paper from the depot, also called "issue related documents." There are usually three such barcodes printed on one 8 ½ X 11 sheet of paper. The paper may be thrown away once the transaction is complete; there is no need to file any documentation, it is all stored electronically.

Smartcards take the place of written signatures. The smartcard is inserted into a handheld computer by the person taking receipt of the materiel in order to verify whether the transaction is valid. The owner of the smartcard must also enter his/her four-digit personal identification number (PIN) for added security. This PIN is not transmitted through radio frequency, but remains local on the handheld computer for security purposes. The Air Force uses signature cards to determine who gets smart cards; only those authorized to receive materiel are issued smartcards.

The system of barcodes functions in a hierarchy-like system within a shipping container. Every container has a military shipping label (MSL) that is a 2-D barcode that includes basic transportation information. The shipping container is divided internally by tri-walls that also have a MSL. Each MSL can hold up to five lines of supply data: RIC routing, unit of issue, quantity, condition, and unit price. Within the tri-walls are the 1348 linear barcodes that are used by SATS.

SATS is designed to run on any 32-bit windows platform. All of the handheld computers are currently running Windows CE. An Oracle database currently runs on Windows NT servers but a move is being made to upgrade them to Windows 2000. The SATS workstation only requires the Oracle client and a connection to the base local area network (LAN) to function.

3.1.5 Bench Stock

Bench stock consists of very small general-purpose parts such as nuts, bolts, and washers. Every aircraft maintenance unit (AMU) has its own inventory of bench stock. Bench stock is stored in approximately 2" X 2" bins in drawers that are all housed in a shelf system. The bins are labeled with a part name, part number, and a barcode that contains this information; however personnel at Hill AFB do not utilize the barcodes.

As maintenance personnel need bench stock, it is taken from the drawers without any documentation. Bench stock is inventoried by hand every Thursday. An exact count is not made, just an approximation (there may be 100s of small parts in a given bin). There are approximately 50 drawers, with 100 bins per drawer. Inventory takes approximately 20 minutes for one person to complete. If exact counts were made, this time would increase dramatically. If

the bench stock is depleted, supply personnel will pull from deployment stock, if the deployment stock has been exhausted, personnel will go to another AMU and pull it from their inventory. Deployment stock is a separate storage of spare parts and bench stock that will be shipped with the AMU if it is deployed. Deployment stock must also be inventoried every Thursday because it is not known if parts have been taken.

Parts have a designated maximum that they are allowed to keep in stock to keep costs down. There is no set reorder point, parts are generally ordered based on a guess, and generally when stock drops below approximately 50%. Specific knowledge of the parts is needed to know when and how many to order, this is done on an individual part-by-part basis by supply personnel who have experience with the stock levels of the parts. Re-ordering of bench stock is done through CAMS and usually takes five days to arrive.

3.1.6 Automated Tracking System

Automated Tracking System (AMTS) is a new program that currently operates within Hill AFB. This system tracks the time it takes from when a part is pulled from the shelf to when it is shipped. It also tracks the time between pickups and deliveries on the base. Deliveries are given a requisition number which is converted to a barcode on a pickup/delivery document. Deliveries for this system are quite efficient, averaging between 30 minutes and 2 hours. All of the data is stored in a local database. This system is not used for any assets entering or leaving the base, only those traveling around the base itself. Implementing a system such as this on global scale, would greatly expedite the Air Force's supply chain.

3.1.7 Deployment

Personnel at Hill AFB do not handle the packing or shipping of crates for deployment. Crates for overseas deployment are marked with a yellow service tag and contain a manifest to pass through customs. Often these manifests do not accurately depict the full content of the shipping crate and crates must be physically checked to verify the contents.

3.2 Supply Chain Operations Suggested by the Air Force Supply Manual (AFM 23-110)

The following section gives excerpts from the Air Force supply manual (AFM 23-110) in order to give the reader an overview of the sections of the manual pertaining to asset visibility.

3.2.1 Receiving

The following is an excerpt from the Air Force Supply Manual (AFM 23-110) detailing the process for receiving:

> **5.41.2.** The Wholesale and Retail Receiving/Shipping System (WRRS) (D035K) for all Air Force Materiel Command (AFMC) Air Logistic Centers (ALCs) interface with the existing Automated Warehouse System (AWS) and incorporates barcode technology in the wholesale/retail receiving function.

5.41.2.2. The Wholesale and Retail receiving functional area processes receipts for posting in the D035K system and AWS through system terminals. WARRS will utilize pre-positioned data whenever possible. If pre-positioned data is not available, all data will be scanned/keyed to complete the applicable input. This process requires in check, verification, inspection, remote terminal operation, match back of output to materiel, and routing materiel to appropriate areas.

5.41.2.3. The distribution Wholesale and Retail receiving function provides support to the materiel management directorate for inventory control of materiel received in the wholesale environment. Materiel is processed from on- and off-base organizations in such a manner as to ensure that shipments are correct, inventory records are updated, back order requisitions are released, and materiel is routed to the storage facility customer.

This process differs radically from the method used at Hill AFB and many others. The WRRS and AWS systems, for instance, were not found at Hill and therefore none of the above procedures are followed.

The two systems, WRRS and AWS, with their barcode technology would seem to make the shipping and receiving area a much more efficient process. The system contains provisions to scan in/out materiel via barcode so that the information will be automatically entered into the database. This system allows the user to verify a package has been received so the necessary parties may be notified, or the materiel may be routed to an alternate destination.

3.2.2 Receipts From Government Activities

The following excerpt from the Air Force Supply manual (AFM 23-110) details the verification of receipt of items from other government entities:

5.43.1. Receipts from other Air Force, GSA and DOD activities will normally be received on the copies of documents accompanying the shipment as provided in section 5A. In case of shortage of any or all of these copies, sufficient copies to make up the shortage will be prepared by the receiving activity. Care will be exercised to ensure these copies are legible. Information required will be obtained from package marking, item identification tags or labels, requisition files or transportation records. When the number of copies received are not sufficient for processing, facsimile copies may be used. A minimum of three (3) copies of the receipt document is normally required for receipt processing.

5.43.1.1. Document Control Copy. All pertinent in-checking/inspection data will be annotated on this copy.

This is the source document that supports the accountable record update. Forward this document to the document control unit for filing immediately upon completion of in-check/inspection actions.

5.43.1.2. Remote Input Copy. This copy is forwarded to the receiving remote for accountable record update input after in-checking/inspection actions are completed. The method of using this copy is optional for activities using LOGMARS equipment in the receiving operation.

5.43.1.3. Warehouse Copy. This copy is attached to the materiel after in-checking and inspection actions are completed. The warehouse copy may be left attached to the materiel and forwarded to the storage area after processing, or destroyed as determined locally.

5.43.1.4. Locally, additional copies of the receiving document may be required for activities as follows:

5.43.1.4.1. Accounting and finance or contracting agencies.

5.43.1.4.2. "Prime IM" - In ALC wholesale receiving, this copy is required when the whole or a partial quantity received is determined to be MILSTRIP condition code "E" at the point of receipt. Component parts shortages will be listed on this copy or furnished as an attachment. When a partial quantity is condition code "E," the list must be furnished on or with the extract document as described above.

3.2.3 National Stock Numbering System

The military does have its own national stock numbering system to identify materiel. The following is an excerpt from the Air Force supply manual (AFM 23-110):

7.8.1. The NSN is a 13-digit (all numeric) number. It is divided into two parts:

7.8.1.1. The first four digits are the FSC number assigned to the item establishing its relationship to other items identified within the same FSC.

7.8.1.2. The last nine digits of the NSN are referred to as the NIIN,

7.8.2. The permanent system control number (PSCN) is a 13 digit, (alpha-numeric) number. Item identifications assigned PSCNs will be used to identify preferred or replacement items resulting from new or revised superseding specifications/standards determined by the preparing activity for specifications standards and implemented by the preparing activity for item reduction is assigned FSCs. These items are not currently stocked, stored, or issued, but are authorized for procurement. The AF submitting agency will not use the PSCN when submitting requisitions. The requiring activity will satisfy their requirement by submitting a requisition for the specific cataloged NSN. If no NSN, requisition appropriate part number. The agency maintaining the PSCN will take action to convert PSCN to an NSN and honor the requisition.

7.11. Interchangeability And Substitution Data.
7.11.1. Item relationship data are developed, approved, and documented for sending and use throughout the USAF and/or by other DOD activities, as required, through the media

of the USAF Interchangeability-and Substitution (I&S) Grouping Program. These data are an essential element in logistic operations both in terms of materiel management and utilization functions. Use of these data in the accomplishment of these functions provides for more effective new item entry control, utilization of available assets, supply support and orderly attrition of items from the inventory. For terms and definitions see chapter 1, paragraph 1.6., of this manual and the introduction to the I&S grouping stocklist (SMSG).

7.11.4. The I&S relationships are currently recorded in the I&S maintenance system (D043B), HQ AFLC and are distributed through the SNUD system (D071). These data are also available through D046 (BASE) interrogation as phrase coded relationships in the CMD record, that is, "Interchangeable With," "When Exhausted Use," etc. These sources are an official Air Force media for reflecting such determinations. I&S relationships are contained in the D043A system and published only after careful research; technical comparison and assurance that the relationships revealed are within accepted engineering practices and meet functional, physical, qualitative and prescribed performance requirements.

3.2.4 Master Item Identification Control System (MIICS)

The following excerpt from the Air Force supply manual (AFM 23-110) details the MIICS:

7.15.1. The MIICS program is a computerized system in operation at HQ AFLC and is designed to be a central repository for federal catalog data for all air force used NSNs; related data applicable to specific NSNs; and AF catalog management data. The MIICS system also retains data on NC, ND, and K numbers. The system assures compatibility between AF management records and corresponding federal records, and supports other ADPE systems.

7.15.1.1. The federal catalog data as received from the Defense Logistics Services Center includes item name, item name code, manufacturers' codes, part numbers, NSN, and federal user data.

7.15.1.2. Management data as contained in the IM/FSC stock list. This includes fund code, ERRC code, unit of issue, unit price, source of supply, AF IM/FSC manager, quantity per unit pack, standardization status code, shelf life code, security code, acquisition advice code, PSC, and budget code.

7.15.2. The MIICS was designed to perform several major functions in support of cataloging and item identification. These include:

7.15.2.1. Compatibility check and balance system to insure that the federal and AF catalog data remains in proper alignment. Exception listings are prepared weekly and are forwarded for appropriate corrective action by the responsible cataloging component.

7.15.2.2. Reports and data summaries used for management and planning purposes.

7.15.3. The utilization of MIICS by AF activities is encouraged. The file data, air force and federal, will be extracted from the master file and forwarded upon receipt of a request from an AF activity, other federal agencies, or contractors. Requests should be prepared in accordance with paragraph 7.80.1. A list of all option codes are reflected in paragraphs 7.80.4.

7.15.3.1. The established method of requesting MIICS file data is by the submittal of keypunched cards in the format specified in section 7B. Special request for data may be made for tape input and/or output. Formats for tape input are also reflected in section 7B.
7.15.3.2. Request for file data shall be submitted to LMSC/SORE, ATTN: D046 Product Manager, WPAFB, OH 45433,

3.2.5 STOCK NUMBER USER DIRECTORY (SNUD) (D071)

7.41. Purpose. The SNUD is an Air Force Logistics Command (AFLC) operated data system which provides selective automatic distribution of stock number oriented management data. It is a means of associating stock numbers with stock record account numbers (SRANs) or assigned user account numbers to provide tailored automatic distribution of management data to meet the individual needs of each user registered in SNUD. This tailoring is based on user established interest in a specific stock number and type of management data registration established by the user. With selection of required transactions being accomplished mechanically by SNUD, the need for manual research of reference documents, such as stock lists, machine listings, etc.., to keep base records current has been minimized.

3.2.6 SBSS

1.13.2. Scope. The SBSS, like any supply system, involves basic transactions. These include filling issue requests for supply items, requisitioning items when there are not enough in stock to fill requests or maintain stock levels, processing items that personnel have turned in, handling backorders and shipments, and finally, taking inventory. To handle the required accounting records for all of these transactions, the SBSS consists basically of four major processes: item accounting, accounting and finance functions, file maintenance, and management reporting. This section describes these processes in some detail.

1.14. Item Accounting.
1.14.1. Item Accounting is divided into many small processes all started when a person inputs data on a computer terminal. At that point, the main analysis program looks at the format of the input and identifies the kind of transaction that the operator entered in the system. The transaction may be one of these: issue, due-out, due-out requisitioning, receipt, due-out release, turn-in, shipment, or leveling/ file status. The program next checks the input data against the basic of the activity initiating the input to be sure the data are compatible. After the program finishes these checks, it starts the transaction process the analysis program first identified.

3.2.7 Mission Capable Asset Sourcing System (MASS)

1.6. MASS Sourcing.
1.6.1. Sourcing, as used in MASS, means using lateral support to look for assets at other bases. The system provides automatic or manual sourcing options for MICAP requirements. Through sourcing, MASS requests asset balances from other known users of the item on a real time basis. When retrieving remote asset information, balances are grouped into either accessible or inaccessible assets.

1.10. System Components. Components of MASS include the following:
1.10.1. User PCs. Personal computers are used for normal day-to-day processing. They pass transactions to the SBLC for SBSS processing and updates to the MASS database. After MASS processes the request, all responses are returned to the PC and written to its hard disk. The user is then free to review the MASS output response on the PC at any time.

1.10.2. SBLC. MASS maintains its own active database on the SBLC. This database consists of such things as lateral asset information, cannibalization actions, etc. MASS also requires user terminals to be registered to system code "GW" in the IPCs NAPZOO file. In addition to its own database, MASS accesses the normal supply database to determine asset balances when required. When inputs are made to MASS which require SBSS processing, MASS generates and passes these inputs to the SBLC. In passing these inputs, the user-ID of the individual creating the MASS input is also passed to the SBLC and is subjected to normal supply security processing edits. If a user-ID is not authorized to process a certain TRIC, then the supply security system will reject the input.

3.3 Visibility Technology Currently Implemented by the Air Force

Based on observations and interviews with personnel at Hill AFB, there is currently a very limited amount of visibility technology currently implemented within the United States Air Force. At Hill, barcode scanners cannot even be found. Most transactions and record keeping are done on paper or manually keyed into the SBSS database. The same can be said, for the most part, of the rest of the Air Force. There are limited implementations of bar codes and advanced database systems that are beginning to emerge.

3.3.1 Tracker

Tracker is the requisition information system resident in the AFMC. Tracker is a secure system, running off a secure server that contains classified information. As such, specific information on Tracker is sensitive and not releasable to an independent civilian research team such as ourselves.

Tracker is a D087T program, part of a broader series of D087 programs. It is an Internet website that provides users with information from its data warehouse. This data warehouse is populated by numerous data systems used by the DoD. The web site actually acts as front end for the Oracle database.

Tracker is specifically designed to disseminate information related to requisitions, specifically those of the flightline base level user. Tracker feeds requisition information to the lowest level personnel who can benefit most from it. Tracker works by obtaining copies of the transactions that are transmitted between computer systems used to acquire, store, repair, and move assets for the Air Force. The data extracted is raw data, data that has not been scrubbed or cleaned. Tracker organizes transactions by categories enabling personnel to make queries based on those categories. Tracker also has the functionality to extract data from other databases such as WSMIS-SAV and DO43 and display it via its web interface.

3.3.2 Enterprise Data Warehouse (EDW)

The Air Force's EDW is scheduled for full operation in 2007 (Norman 2001). EDW provides Air Force personnel with a complete spectrum of integrated combat support data through a web-based interface. EDW integrates data from 26 legacy systems including maintenance, supply, transportation, and financial data repositories. EDW enables Air Force personnel to access to accurate, real-time supply chain data on aircraft-combat status, availability of critical parts, outstanding maintenance orders, and the status of financial transactions (www.informatica.com).

Mike Riley, EDW program director for the Air Force says "EDW consolidates large volumes of data from disparate systems, providing our personnel with a single online resource to make faster, more informed supply chain decisions . . . Leveraging data integration technology like Informatica, we have successfully consolidated data from 26 legacy systems into one robust, scalable data system to improve our operational efficiency (www.informatica.com 2003)."

EDW, in addition to integrating information provides enhances analytical and query functions that can produce custom reports to the user with significantly reduced response times. Clarence Sech, Materiel Systems Group supervisory program analyst says "This will provide commanders and warfighters the information they need to verify suspected trends and look for unknown ones before they restrict combat capability . . . The can also determine if they need to order different parts, and based on that, better define requirements and budget (Norman 2001)."

Pertaining to commercial best practices, surveys have shown that nine out of every 10 of the nation's top retailers are using data warehousing. In addition so do six of the world's largest airlines, 75% of the world's leading banks, and 95% of the world's leading telecommunications companies. The Air Force has also visited the Wal-Mart headquarters in Bentonville, AR to preview Wal-Mart's premier data warehouse model.

Milestone B – Identification of Air Force Improvements

There is room for improvement in many areas of the Air Force's current supply chain.

4 Area Improvements

Any implementation of technology or procedural enhancements to the supply chain will be futile unless personnel actually use the technology and follow procedural guidelines. Better enforcement of the Supply Manual procedures would improve the efficiency of the supply chain by itself. Personnel often get in the habit of doing things there own way and circumventing the procedural guidelines in an attempt to create a shortcut for themselves, but are in fact reducing visibility in the overall supply chain. One example of this is when personnel opt not to enter a requisition or a receipt in the SBSS database to save time. Much of the technology and processes designed to improve the supply chain is not being utilized by Air Force personnel because in its current state the technology tends to be more cumbersome than manual procedures.

4.1 USAF Personnel Feedback

Master Sergeant Doug Doughty, the superintendent of maintenance scheduling, says that the CAMS and SBSS systems are overloaded (there are over14,000 users at Hill AFB alone).

Todd Levings, supply personnel, would prefer Mission Capable (MICAP) tracking at the base level rather than through RSS due to hassle of communicating with RSS through email or telephone, and the fact that the hours are limited due to the time zone difference. Mission Capables are the term given to parts that are necessary for an aircraft to complete its mission. Mr. Levings would also prefer a consolidated database so that only one resource needs to be checked, rather than the multitude that currently exists.

4.2 Supply Database Improvement Areas

There are more than a half-dozen databases that personnel must inquire to check the availability of a part. Databases are too specialized; personnel have to know which database to check for a particular type of materiel. The databases are often inaccurate because personnel fail to update them or they are only updated periodically (sometimes as little as once a year). A centralized database that has global visibility would be very beneficial to the Air Force. This database should also be web-based so that personnel anywhere can check the availability of parts and the status of their shipment. This database should be updated in real time such that when a part is no longer available the system is updated. This issue has been addressed above in the JTAV vision, however I think this issue is much further from being solved than the JTAV initiative implies. At present, there is no consolidation at Hill AFB or any other base that personnel had been stationed at.

4.3 Central Receiving Improvement Areas

Central Receiving is obviously the bottleneck of the supply chain. An appropriate method of notifying the concerning party that their package has arrived is needed. Arriving packages need to be properly accounted for, verified, and inspected. With a consolidated database in place, the

package could be scanned such that the system is updated with the package arrival. The package could then be fed into the Automated Tracking System (AMTS). At a bare minimum, labeling procedures could be standardized such that receiving personnel would know exactly where and to whom the package is intended and could send an email notifying the appropriate party. Simply setting the package aside until someone comes looking for it is certainly not appropriate.

A problem is also created due to the fact that receiving is outsourced. The outsourcing party will have technology, databases, and systems that differ from the Air Force and may not be able to interface or communicate with Air Force systems.

Even if barcode technology is used, there is still the issue of labeling and scanning all of the packages. Every package must be scanned individually by a handheld barcode scanner and line-of-sight must be attained with each label. This creates a high probability of a package being missed when multiple packages are brought in at a time and many packages must be scanned. Furthermore, barcodes labels may be damaged in the shipping process rendering them unable to be scanned.

4.4 Bench Stock Improvement Areas

At present there is no documentation whenever a part is removed from bench stock. There are also no set reorder point levels for individual parts or a means to accurately inventory all of the parts. Advantage could be taken of the barcode labeling that already exists on the bench stock bins. It is not known the exact information the barcodes contains, but at a minimum it would be a reference point for a database to extract further details. A handheld barcode scanner could be utilized to scan the bar code on the bin whenever a part is taken from the bench stock. This scan would tell the database that a particular part has been removed. Preset order points could be designated in the database to automatically order the stock through CAMS or at a minimum provide a printout to tell supply what needs to be ordered and how many. This system would be of little cost and eliminate the need for a manual inventory of bench stock and deployment stock. Database analysis could also be performed to see which parts are consistently out of stock so that the re-order point or order quantity could be set higher.

4.5 Receipts from Government Activities

This process is quite cumbersome and lacks automation and electronic documentation. The forms of receipt are handwritten. And information from packages is obtained from human readers who transcribe the labels or tags attached to the packages. There is also a superfluous amount of documentation required: a document control copy, a remote input copy, and a warehouse copy.

4.6 National Stock Numbering System

The national stock numbering system (NSN) was designed to identify classes or types of matericl, not individual itcms. Thc NSN lacks thc sizc and dimension necessary for individual item identification. The NSN also lacks a checksum or check digits for error control and verification of a valid NSN.

Milestone C – Automatic Identification Technology

5 Automatic Identification (Auto-ID)

To achieve real time visibility of information, the following are needed (Agarwal 2001):

- Real-time data acquisition methods
- Conversion of acquired data into relevant information: using standardized, secure representation
- Instantaneous access to this information

Tagging would enable continuous, accurate, and real time information on products, providing an unprecedented level of visibility in the supply chain.

5.1 Basics of Automatic Identification

Included under the automatic identification umbrella are the following technologies (Agarwal 2001):

- Bar code
- Optical character recognition
- Radio frequency ID
- Machine vision
- Magnetic stripe
- Smart cards
- Touch memory
- Voice data entry
- Radio frequency data communications (RFDC)

All code-reading systems for automatic identification share the following features (excerpt from Agarwal 2001):

- There is a product, part, component, package, pallet, tote box, barrel, etc. Accurate identification of this item while moving into or through production, warehousing, or the distribution pipeline will contribute to the benefits case.
- A label, tag, or coding device is affixed to the item so that it can be automatically read to identify what the item is, where it came from, where or to whom it is going, or whatever else might be needed by the user.
- An automatic or hand-held bar code reader, optical character reader, magnetic stripe reader, vision system, or radio frequency interrogator will read the code, validate it, and convert the content into system-meaningful control and information output.
- The code reader transmits the output to networked PC's, mini-computers, relays, solenoids, microprocessors, programmable controllers, diverters, counters, video displays, horns, bells, whistles, etc for data manipulation or communication.

5.2 Auto-ID Applications & Benefits (Industry)

5.2.1 Improving On-Shelf Availability

In industry, in order to improve on-shelf availability focus must be placed on the ordering process and the backroom-to-shelf replenishment process. The activities of each SKU may be monitored at various locations through tagging. Tag readers can provide visibility as to what is available on the shelves and in the backrooms. This system can send up a flag to inform managers that a requisition of more products needs to be made in the event that an inventory levels drop below a desired metric.

5.2.2 Improving Security of Products

The capability of Auto-ID to locate and quantify products through the use of tags has valuable implication for ensuring the integrity and security of the supply chain in terms of theft and counterfeiting. Through RFID, security may be enhanced by monitoring if a product leaves an area without authorization. RFID can also verify the authenticity of products that may have been counterfeited. In order to determine whether RFID and Auto-ID technology would be beneficial to the Air Force in this respect, analysis must be performed to determine the current levels and root causes of shrinkage and the realistic level to which this shrinkage may actually be reduced through Auto-ID technology. The Air Force is not a retail outlet so shoplifting is not an issue. However, there can be no price tag placed on the cost of the theft of munitions if they end up in the wrong hands.

5.2.3 Automated Proof of Delivery (POD)

Through the use of tags and delivery, obtaining proof of delivery may be automated, eliminating errors from manual counting and inspection of materiel. Products will be accounted for simply by passing through tag readers at the receiving point. The Air Force would receive potential savings in the amount paid for products never received and the personnel devoted to counting and checking incoming freight. Cost saving could be demonstrated by checking the average level of invoice adjustments in a year, number of personnel devoted to investigate claims and negotiate with vendors, outside costs such as attorney fees, and the costs due to expedited delivery on materiel not received.

5.2.4 Eliminating Stock Verification

Inventory may be performed automatically through readers that poll tagged products. This allows personnel to have real-time visibility of inventory and eliminates the time-consuming and often inaccurate process of manual inventory. This is a drastic improvement even over the recent barcode technologies of scanning and labeling which are still subject to human error and consume time with manual scans of every individual item. Cost benefits could be shown through analysis on personnel required to perform inventories and the average man-hours spent on stock-checks, delays due to incorrect inventory levels, and the need to verify that items entering or leaving the warehouse have been properly labeled and scanned.

5.2.5 *Incorporating Shelf-life of Products*

With tagged products, complete visibility of product age is possible, enabling the FIFO inventory system to be implemented. This technology would prove beneficial with food products that may have a designated shelf life, as well as ammunition and chemicals. An alarm might be triggered by the system if a product on the shelf exceeds its designated life, or comes within a predetermined limit of its expiration date.

5.2.6 *Reducing Inventory Levels*

Auto-ID can reduce the level of inventoried carried by allowing managers better visibility into inventory levels such that order cycle times may be reduced. Forecast information will also be much more accurate with the implementation of Auto-ID through continuous monitoring of inventory levels and demand patterns. Auto-ID reduces variability in ordering (thus lowering safety stock needed). It increases speed and accuracy of planning and increases flexibility in responding to unexpected demand. It enables Just-In-Time (JIT) strategies, such as produce-to-demand v. produce-to-forecast, and controls the bullwhip effect by co-coordinating information and planning along the supply chain through information and product visibility. Auto-ID also increases the accuracy of information. In general, the higher the accuracy of the inventory, the lower the level of buffer stock that needs to be held. Lastly, Auto-ID reduces inventory levels by enabling a shift from make-to-ship or make-to-pack towards make-to-order. Cost benefits could be demonstrated through analysis on the estimated percentage reduction in inventory levels should Auto-ID be implemented, the cost of capital tied up in inventory, the associated storage costs (personnel, number of warehouses, etc.), and the cost of transportation of inventory.

5.2.7 *Systems 'Integration'*

Most manufacturers use different systems than their retailers and suppliers, and more often than not, have a variety of different systems within the company. Auto-ID can ease the pain of systems integration by allowing data to be maintained on the products themselves. The read/write or read-and-append feature of tags means the same label could hold shipper, customer and carrier data. The data would, obviously, have to be compatible with the existing systems. Auto-ID can therefore provide companies the benefits of integrated systems without the cost of standardizing systems.

5.2.8 *Automatic Reordering*

There is on-going research into products that may automate the reordering process. For example, a fridge could automatically reorder milk when existing stock depletes or goes out of date.

5.2.9 *Active Management*

Through the use of tagged components the Air Force can monitor the environment materiel is subjected to. For example, the temperature of materiel may be actively monitored throughout its transportation and storage cycle to ensure it does not go above or below specified settings. This could be valuable to sensitive materiel such as weapons, chemicals and food (Agarwal 2001).

5.3 Open-loop Automatic Identification

Open-loop (information-oriented) Auto-ID provides the infrastructure for the extraction, networking and storage of production data, distribution, retail, and usage or disposal of the product. Deemed "open-loop" because Auto-ID information is not used to directly control an operation, open loop provides benefits because of the increased accuracy, quality, and timeliness of data within existing information systems. Applications include (1) Production: direct tracking of items for multiple customer orders, quality monitoring, (2) Distribution: monitoring of condition of produce, predicting order delivery time, (3) Product: sales monitoring, product condition monitoring-dynamic sell by dates, stocktaking, (4) Domestic: access to product instructions, home inventory, disposal sorting (McFarlane 2002).

5.4 Closed-loop Automatic Identification

Closed-loop (decision-oriented) Auto-ID has the ability to consider data to make a decision and take a specific action. Applications include (1) Production: alteration of production sequence, product customization, late order changes, (2) Distribution: optimized truck utilization, delivery of complex mix products and customers, (3) Retail: more accurate and predictive theft detection, higher levels of automated surveillance possible (4) Domestic: automated cooking of more complex food products, adaptive washing, cleaning, cooling operations (McFarlane 2002).

Due to the fact that standards are not prevalent for RFID, closed-loop systems will be accepted by industry faster than open-loop systems that require support from multiple parties. Without the necessary standards various parties will be operating under different standards and unable to interface with each other. Until standardization is achieved in the RFID industry, closed-loop systems will be used, because they do not require identification outside party boundaries (Allied Business Intelligence Inc.).

6 Auto-Id Infrastructure

Within the memory chip of the smart tags discussed above, an Electronic Product Code (EPC) (96-bit code) is embedded for each individual product. As smart tags are scanned by readers, their EPC code is transmitted to the Internet where a database stores all of the information for that particular code.

EPC works together with a Product Markup Language (PML) and an Object Naming Service (ONS). PML is a new standard "language" for describing physical objects to the Internet analogous to the Hypertext Markup Language (HTML), which is the standard language used to display web pages. The ONS is very much like the Internet's current Domain Name System (DNS). The ONS is a computer system that acts as a database, storing all information about any particular EPC code, just as the DNS stores the Internet Protocol (IP) addresses for all text-based web-site names. The ONS database will probably be significantly larger than the DNS server as it will have to store an EPC number for each object that carries and EPC code (Brock *et al.* 2001).

6.1 Physical Markup Language (PML)

"PML is intended to be a common 'language' for describing physical objects, processes, and environments." PML is a general, standard way of describing the physical world. The purpose of PML is to provide a language for remote monitoring and control. Such applications include inventory tracking, automatic transaction, supply-chain management, machine control, and object-to-object communication.

PML is very similar to the Hypertext Markup Language (HTML) which has become the standard for publishing web pages on the internet. More generally, PML is kin to the Extensible Markup Language (XML) of which HTML is a subset. PML uses the same format and structure as XML, which is a set of tags that enclose text to delineate a specific meaning or purpose (Brock 2001b).

PML seeks to provide broad definitions of objects, describing objects in terms of characteristics that are common to all physical items. This should allow the language to be implemented across multiple industries and applications, rather than one particular focus. PML tries to provide a single representation for a physical object. If there are multiple ways to describe the same object, PML will arbitrarily select one so that data translation occurs when encoding or viewing, not in interpreting what is being viewed (Brock *et al.* 2001).

PML describes configuration, location, time, and measurement of physical objects. In order to provide this information, PML provides a number of constructs and data types. These include a data element, which captures a 'snapshot' of the physical environment. A node element, conveys the hierarchical structure of physical systems. The trace element records the location of an object as well as its location history. The entity element contains information necessary to assign ownership and responsibility for physical objects. There are three more sections of the language: location, date, and measure. The measure parameter might contain data such as weight or temperature (Brock *et al.* 2001).

6.2 Electronic Product Code (EPC)

The EPC was developed as a way to identify all physical objects. The EPC is designed with capacity to enumerate all items that exist in the world, and handle all current and future naming methods. The EPC will be the basis by which to gain database information on a particular item. The EPC will be the serial number so that the product may be looked up and all of the information known may be accessed. The EPC differs from the current standard, the Uniform Product Code (UPC), in that it is able to identify each individual item, not just classes or types of items. The task of enumerating all these is daunting, and requires a code that has a tremendous amount of capacity.

6.3 Applications of EPC

An EPC may even be used with containers. In referring to a particular shipping container, it may be possible to look up the EPC on the networked database and obtain an electronic manifest of

all items located within the container. This can also allow for group tracking. Every time the tag on the shipping container is tagged, a record is also made for all the materiel inside it. EPC will also be very valuable for use with assemblies, aggregates, and collections. Having the many parts of a product tagged independently with an EPC will make the tracking of parts for repair much easier. A repair history can then be kept for each individual part.

There is no reason shipping containers should receive a different code than the EPC. The record of items within the container, as well as the shipping data commonly associated with the traditional codes may be stored on the computer network and automatically associated with the container. Even further, the truck in which the containers are transported, as well as the boxcar, ship, or warehouse, may also receive the same EPC format as the individual product. An EPC hierarchy will represent the state of an item shipment. This hierarchy will shift and change over time. Thus by recording the EPC containment structure, along with transition times, a partial history of the product can be logged (Brock 2001a).

6.4 The Virtual and Compact Electronic Product Code

This is an extension to the EPC concept to address unique identification of batch products, component types, and physical configurations (Brock 2002b). There are also shorter, 96bit and 64bit "compact" versions of the EPC (Brock 2002a).

7 Auto-ID based control

A control system can be defined as "the process of adjusting appropriate variables in order to direct the performance of an operation towards a target level". It may be further broken down into three divisions (1) Sensing – measurement of information about the state of the operation, (2) Decision – the process of determining the appropriate action to take based on target performance metrics and the current state of the system (3) Action – executing the decision.

Conventional control may be enhanced by Auto-ID data. This may be accomplished by the linking of Auto-ID data with existing commercial information and control systems and using Product ID data to improve the accuracy, efficiency, and hence quality of decisions and their effective execution.

Auto-ID Driven Control – Auto-ID driven control is based on the existence of an intelligent product. "An intelligent product is a physical and information based representation of an item which (1) possesses a unique identification, (2) is capable of communicating effectively with its environment, (3) can retain or store data about itself, (4) deploys a language which can articulate its features, production, usage, disposal requirements, etc., and (4) is capable of participating in or making decisions relevant to its own destiny on a continuous basis (McFarlane 2002)."

There are two levels of intelligent products: Level 1 and Level 2. Level 1 product intelligence allows a product to communicate its status (form, composition, location, key features), i.e. it is information oriented. Development is already underway. It is being tested in field trials and has

the potential to bring benefits in the short-term (2-5 years). Level 1 product intelligence enables real time product tracking, and product history records.

Functionality of the Level 1 intelligent product includes (1) automated proof of delivery; no need for invoice adjustments, (2) improved accuracy of on-hand inventory due to automation, (3) locating products can be done accurately and efficiently, (4) customized products with the same exterior appearance can be easily identified and sorted, (5) embedded tags are physically more robust in the hostile distribution environment, and (6) anti-theft security will be increased.

Level 2 product intelligence allows a product to assess and influence its function (e.g. self-distributing inventory and self-manufacturing inventory) in addition to communicating its status (decision oriented). Level 2 products have all of the functionality of Level 1 products plus product status information for a dynamic picking process for stock rotation and dynamic product costing for rushed or reworked orders. Level 2 also allows for option assessment and negotiation for real-time delivery planning based on less congested traffic routes and real-time delivery allocation in the event of a system disturbance (e.g. delay, breakdown) (Zaharudin *et al.* 2002).

Interviews with Consumer Packaged Goods (CPG) leaders have revealed the following key insights of emerging Auto-ID technology" (excerpt from Kambil and Brooks 2002)

- Industry-leading companies will gain measurable business advantage by reducing inventory and out-of-stock scenarios at critical points in the value-chain, and will further improve results by becoming increasingly responsive to shocks in supply and demand
- The most significant supply-chain benefits will be enabled by shared implementations across organizational boundaries
- Despite the larger benefits of shared implementations, companies will initially develop focused applications that offer proprietary benefits and are easier to justify internally
- As tag costs diminish, value will migrate from tagging shipping pallets to tagging cases to tagging individual items. Consumer goods manufacturers will likely employ case-level tagging to track products across the value chain and will gain significant benefits from these efforts. Retailers, in contrast, will gain greater benefit by leveraging the ability of item-level tagging to improve valuable in-store operations.
- Important issues companies must address before they can realize value from Auto-Ids include the upfront costs of deploying readers, of purchasing (and/or developing) software to capture reader information, of ensuring the ability of technologies to scale as data requirements grow, and of integrating new hardware and software with existing systems operate by numerous companies across the value chain
- A number of viable business models will likely enable Auto-ID deployment depending on the expected kinds – and levels – of proprietary versus shared benefits
- Companies will not accrue the full value of shared benefits from Auto-ID unless and until their industries develop a consensus on an appropriate business model (or models) for deploying Auto-ID systems

8 Auto-ID costs, standards, & viability

Currently, advanced Auto-ID technology is fairly expensive and vendor-specific. Low-end tags sell at about $0.40 a tag and low-end readers cost between $300 and $500. Technology being vendor specific prevents the implementation of tags and readers across multiple users who use technology from differing vendors. This technology will be somewhat limited in the commercial arena until standards are formed. The Air Force and military as a whole can avoid this dilemma as their supply chain is autonomous, as long as the Air Force remains consistent in its technology Auto-ID implementation should be successful.

Examples of Commercial Practices - Goldwin Sportswear Europe, the European branch of one of the largest branded sportswear companies in Japan, has implemented RFID technology on individual clothing items to track shipments, prevent unauthorized out-of-area distribution, and authenticate products. CHEP, a provider of pallets and containers, is testing an RFID system to track its pallets. Associated Food Stores, a cooperative of over 500 supermarkets in the western United States, uses an RFID-based real-time locating system at its distribution center to improve yard management. The system informs personnel when trailers enter or exit the yard and specifically where in the yard a given trailer is currently located. The status of a trailer may also be obtained. If the trailer is a refrigerated unit and the door was left open, a temperature spike would alert personnel (Kambil and Brooks 2002).

9 Auto-ID Deployment

9.1 Technical issues

9.1.1 Tags and Readers

Frequency – RFID systems must have their own band of the wireless communication spectrum to prevent interference from other frequencies. This band must be maintained across international lines. The frequency selected affects the physical design and size of the antennae, as well as the operating range of tag readers and the possibility of interference between RFID systems. Research is currently underway which is exploring the use of "agile" readers capable of switching to different frequencies for different locations and environments.

Physical space – The environment in which the RFID system operates plays a critical role in determining the performance of Auto-ID technology. Radio signals from low-cost tags is relatively week (a few cm to a few m), and interference from water and metal can degrade the signal. Water absorbs radio waves while metal reflects them.

Throughput – RFID systems signals are fast and automatic, but not instantaneous. With tags in close proximity to each other, it is possible that two tags can respond simultaneously to a reader's query, distorting the signals. In addition, readers in close proximity can disrupt each other. Protocols are being researched which reduce or prevent these "signal collisions" but they have a side effect of reducing the speed of reading tags (Kambil and Brooks 2002).

9.1.2 Data management and network services

Data management software is required to: (1) capture data from readers (2) manage data storage (3) aggregate data (4) process data so that it may be easily read and understood by personnel.

9.1.3 Integration software and services

EPC-driven applications will have to integrate with existing applications using specialized integration software that aggregates large amounts of data from tag readers and interfaces with existing systems. This will be especially true if the Air Force wishes to implement RFID technology to communicate with their current databases.

9.2 Economic Issues

Current RFID technology costs are multiples of what they need to be for economic viability. Projections say the cost of passive tags will lower from $0.40 to $0.20 in 2004 with additional scale driving the cost to $0.05 by 2006. This cost will still be five times the cost of the current $0.01 cost of bar code technology (Kambil and Brooks 2002).

10 Auto-ID Deployment Pathways

Alan Haberman (Kambil and Brooks 2002), a central figure in the widespread adoption of the UPC and barcodes, noted four key success factors for developing and deploying the previous generation of Auto-ID technologies:

1. An initial focus on contemporary instead of future applications
2. A conservative estimate of the benefits
3. Getting buy-in of key manufacturers and retailers for critical mass
4. Establishing a committee of influential executives to drive standard-setting and deployment

11 Product Driven Supply Chains

11.1 Supply Chain Analysis Model

There are two main types of products: innovative and functional. Innovative products have a lot of variation in the type of product; for example, there are many different variations of the computer. Innovative products are also characterized by an unpredictable demand. They tend to be expensive in nature and require a market-responsive model that can adapt to the ever-changing technology and rapid fluctuations in demand. Functional products are generally characterized by a more predictable demand which is easier to model. Products from the high tech sector tend to be innovative in nature. Determining whether a product falls in the innovative or functional category will help determine what type of Auto-ID technology should be employed. Table 1 gives an overview of the differences between innovative and functional products.

Table 1. Determination of Functional vs. Innovative Product (Zaharudin 2001)

	Innovative	**Functional**
Aspect of Demand	Unpredictable demand	Predictable demand
Product Life Cycle	3 months to 1 year	More than 2 years
Contribution Margin	20% to 60%	5% to 20%
Product Variety	High(often millions of variants per category)	Low (10 to 20 variants per category)
Average margin of error in the forecast at the time production is committed	40% to 100%	10%
Average stockout rate	10% to 40%	1% to 2%
Average forced end-of-season markdowns as percentage of full price	10% to 25%	0%
Lead time required for made-to-order products	1 day to 2 weeks	6 months to 1 year

Innovative products require a responsive supply chain while functional products require a lean chain. Table 2 summarizes the characteristics of these two supply chains.

Table 2. Supply chain characteristics for responsive and lean chains (Zaharudin 2001)

	Responsive Chain	**Lean Chain**
Primary Purpose	Respond quickly to unpredictable demand in order to minimize stockouts, forced markdowns, obsolete inventory	Supply predictable demand efficiently at the lowest possible cost
Manufacturing Focus	Deploy excess buffer capacity	Maintain high average utilization rate
Inventory Strategy	Deploy significant buffer stocks of parts or finished goods	Generate high turns and minimize inventory throughout the chain
Lead Time Focus	Invest aggressively in ways to reduce lead time	Shorten lead time as long as it does not increase cost
Approach to choosing suppliers	Select primarily for speed, flexibility and quality	Select primarily for cost and quality
Product Design Strategy	Use modular design in order to postpone product differentiation as long as possible	Maximize performance and minimize cost

A study was carried out by the Auto-ID center on 9,634 firms in the United States, Japan, Korea, and Australia which shows the effectiveness of using a lean chain for functional products and a more responsive, collaborative chain for innovative products. A summary of the study is given in Table 3.

Table 3. Varying levels of integration (Zaharudin 2001)

Form of Integration	Role of Supply Chain	Extent of Integration	Product Management Strategy
Inter-Organizational Operational Excellence	Supply chain is lean and cost efficient. Supply chain operations are standardized for efficiency	Production systems are operated for efficiency and zero defects Suppliers chosen primarily on cost and reliability	Supports total cost reduction Products standardized, not customized. Products compete on competitive prices and offer minimal difficulty and inconvenience of use
Inter-Organizational Collaborative Closeness	Supply chain is part of overall product offering of value to customer	Collaborative forecasting (use same demand forecast Collaborative scheduling (use same schedule) Sharing capacity (use same assets)	Supports differentiation strategies Unique, key customers are targeted
Inter-Organizational Process Integration	Supply chain management focused on internal priorities. Job functions are specialized	Focus on hands-offs and interfaces between internal departments	Primarily supports cost reduction

11.2 Utilizing the Internet for Information Exchange

The emergence of the Internet allows real time information transmission and access to this information from any computer with an Internet connection and browser. This is a tremendous advantage over traditional Electronic Data Interchange (EDI) that uses a direct connection between two computers such as a leased telephone line or a fiber optic cable. EDI dramatically limits the sharing of information, as all parties would have to have direct connections to one another.

The Internet also makes possible Decision Support Systems (DSS) applications to optimize planning for manufacture, inventory management, distribution, customer service, etc. This is accomplished through the implementation of algorithms and heuristics (Zaharudin 2001).

11.2.1 Benefits

Most supply chain issues can be attributed to the following problems: (1) the bull-whip or Forrester effect, (2) poor product visibility, specifically with regard to inventories, (3) poor information sharing and collaboration between parties throughout the supply chain, and (4) using the incorrect supply chain for a given product.

The combination of intelligent products and the Internet can dramatically improve product visibility through the tracking and routing of products. Additionally, products may be self-managed for transportation such that they will be programmed with their end destination. With this technology, products placed on purchased truck space can arrive at their destination on their own. Also, products may be self-picking. Products may be programmed with their due dates such that the FIFO inventory system may be used and products with the closest due dates will be expedited on the fastest means of transportation available (Zaharudin 2001).

11.2.2 Current Developments

Wireless Internet technology is developing rapidly with such technologies such as 3G, 4G, Bluetooth and GPRS due for wide implementation within the next 10 years. The adoption of wireless Internet by end consumers will be tremendous. According to Ericsson the number of the mobile Internet users will surpass fixed line users in 2003.

Internet standards are also emerging rapidly. The Extensive Mark-Up Language (XML) has standards being developed by RosettaNet and OpenBuy. Software vendors such as I2 and IBM believe XML standards for Internet EDI will be robust in approximately 10 years (Zaharudin 2001).

11.3 Future Supply Chain Models

One trend in improving supply chain efficiency is reducing the distance between point-of-demand and point-of supply. This will drastically reduce the transportation time of products. The Air Force can accomplish this by strategically placing warehouses/distribution center to service the most number of bases. Additionally, care should be taken to place these warehouses closest to the bases that consume the most resources, and make sure warehouses that store particular products are near those bases that consume those products.

Further focus should be paid to supplier management particularly those suppliers further up the supply chain. Increased collaboration should be made with suppliers of innovative products, and suppliers of functional products should receive more detailed information on demand to facilitate forecasting.

Emphasis should be placed on how quickly materiel travels through the supply chain not the amount of materiel in the supply chain. This point holds especially for innovative products to prevent them from being out-of-stock (Zaharudin 2001).

Materiel may be traced throughout its lifecycle through the use of tags. The service or maintenance records of a product may be stored on tags for a part and accessed instantaneously for a complete history of the component. In addition, pre-visit diagnostics can be made possible by sophisticated products that can perform self-diagnostics and submit the data either via a self-contained Internet connection or through an RF connection that connects to a server. This remote diagnostics test will eliminate the need for an unnecessary visit by a technician if the item is located in a remote location. This type of technology is currently being implemented by British gas for domestic boilers.

The burden of tagging will be placed on the manufacturer of the product. Tagging will occur on the part or component level such that individual components may be tracked in the repair cycle. There are two main costs incurred in tagging: the initial cost of altering the manufacturing process to install tags and readers, and the on-going cost of maintaining the tags and readers within the system. The individual parties are likely to bare the burden of initial costs. The manufacturers will have to foot the cost of installing tags and the transportation and end-user will have to bare the costs of readers. Cost-sharing programs have been suggested where whichever party benefits most from tagging (the manufacturer, supplier, or end-user) will share the majority of the cost.

Security of data is the main reason that industry is hesitant to adopt intelligent products. There are two ways of controlling data, which deal with the means in which data is stored. Data may be stored on the tag itself, or the tag will redirect the user to an external database that accesses the information through the use of an EPC. The Auto-ID centers of the Massachusetts Institute of Technology (MIT) and the University of Cambridge choose the latter approach in which data is stored on external databases where security can be properly maintained.

Table 4 presents the general model for feasibility analysis detailing issues to consider in implementation of Auto-ID.

Table 4. General Model for Feasibility Analysis

The following issues would be important to consider (Zaharudin 2001):

Issues	Areas to Consider
Technology	-Functionality and availability of software and hardware -Friendly user interface -Technical support and backup -Impact on legacy systems -Implementation and maintenance costs
Standards	-Messaging formats and data parameter definitions -Information transfer standards -Technical architecture standards
Product Nature	-Security issues, esp. for high value products -Product environment, ex. Temperature levels
Monitoring Level / Granularity of Information	-Level of tagging to employ (Pallets – Cases – Individual Products). The cost and benefits of the varying granularity of information have to be weighed up
Data Issues	-Data management -Data ownership. Ex: consumer data, competitor's product volumes -Data accessibility and security. Which parties are allowed to access and decode data -Data storage
Organizational	-Reorganization of business processes both internally and externally for efficient transfer of information across parties -Increase in trust levels and change of mindset
Financial	-Cost benefit analyses -Management of liability and risk if products are in transit or in a neutral warehouse -Revenue sharing mechanisms -Cost allocation mechanisms
Regulatory Issues	-Anti-trust legislation. Ex: the European Commission and Federal Trade Commission have released statements regarding anti-trust guidelines for internet exchanges -Quality Assurance and Health & Safety issues. Ex: quick frozen foods are covered by a Temperature regulation stipulating storage temperature

12 Multi-Band, Low-Cost EPC Tag Reader

Thing Magic LLC and the Auto-ID Center have been in collaboration to design and prototype an open standard RFID reader. This innovative reader will differ fundamentally in both its software and hardware capabilities. RFID will be part of a large, distributed, and dynamic system where each reader is responsible for reading the tags within a given area. RFID readers will act as an interface between relatively "dumb" tags that only store an EPC and highly sophisticated computer and database systems which store and process data.

The various applications of RFID place different requirements on the RF channel of the tag/reader system. Despite the logical data structure and requirements (the type of data being transmitted) being fixed, the air medium will differ by application due to the physics of radio antennas and the means in which radio waves react in different environments. The Auto-ID center believes that different frequency bands (13.56 MHz and 915 MHz) and coupling technologies (near-field inductive or capacitative coupling and far-field radiation) provide different benefits and functional trade-offs such that they foresee two different frequency bands of RFID being used in industry. The Auto-ID center therefore wants to develop a reader that has the versatility of being able to switch between different frequencies.

The implementation of RFID into global supply chains will require standard technology platforms such that tags and readers can operate in the same frequencies all over the world despite various regulatory requirements. Also, it is predicted that the lifespan of RFID readers may be as long as 10 to 20 years while tags may only last a few days to a few weeks. Therefore it is imperative that readers are easily software-configurable so that they may adapt to tag technology that may emerge throughout the lifecycle of the tag reader (Reynolds *et al* 2002).

The Auto-ID center believes that "smart" RFID readers deployed in supply-chain applications should (Reynolds *et al.* 2002):

- Operate at multiple frequency bands
- Speak Internet protocols natively
- Be a part of a client-server system
- Incorporate agent-like behavior

The Auto-ID center also says key features of the new design include (Reynolds *et al.* 2002):

- Frequency agility by means of modular analog signal chains
- Protocol ability by means of a Digital Signal Processor (DSP)-based software radio design
- Standards compliant TCP/IP networking by means of a Linux-based back-end using an Ethernet network
- Low cost because most elements of the system are reused across different frequencies and protocols
- Network-driven protocol upgrades by means of firmware upgrades over an intranet or the Internet
- Interoperability between passive tags, semi-passive backscatter tags, and active tags

13 Auto-ID Center Field Trial

The Auto-ID center developed Table 5 for determining which existing tag and reader hardware should be implemented in their system (Albino and Engels 2002).

Table 5. Auto-ID Center Field Trial

Frequency	Pluses	Minuses
915 MHz	-longer ranges -better for pallet read -Auto-ID spec range for low cost tags	-not as effective on liquids and metals
13.56 MHz	-better for liquids and metal	-shorter range
Applications	**Pluses**	**Minuses**
Portal	-read pallets going through portal (in/out) -no need to shock mount -solid wire long term	-need to distinguish product in and out versus product nearby -many doors need wiring for 100% read assurance
Forklift	-smaller number of trucks to be wired -close proximity to pallet -confirmation at fork lift cap -speed and distance not an issue	-system can only be used at DC or warehouse -too many truck and hand carts at retailer
Availability	**Pluses**	**Minuses**
Savi Portal	-available today -portal application -915 MHz technology	-must be integrated with Auto-ID system
IP Forklift	-forklift application -13.56 MHz and 915 MHz technology	-must be integrated with Auto-ID system -under development

The trial consisted of tags and readers installed at a Proctor & Gamble factory, Sam's Club retail store and distribution center, a Gillette distribution center, and a Unilever distribution center in various cities around the United States.

Conclusions of the Auto-ID center field trial

ONS and the Savant work as expected. They are robust and scalable and require no design changes. Beta implementation is proving to be very stable with 97% item identification realized. The PML language has proven to be the most difficult problem to solve because there is a multitude of ways of describing a single object (Albino and Engels 2002).

14 Radio Frequency Identification (RFID)

14.1 RFID Defined

RFID uses a radio frequency transmission to identify a person or object. An RFID transponder or tag responds to a radio signal sent by a reader. Tags store information such as a serial number, model number, color, or any other characteristics that may be of benefit. Tags are read by a compatible reader when they pass through its radio frequency field. The tags then either transmit information to the reader, or the reader extracts the information from the tag.

RFID, is not a recent discovery, it was first implemented in World War II as a means of identifying friendly aircraft. However, it is only recently that RFID has gained attention as a valuable method of identifying objects on a large scale.

14.2 Current State of RFID Technology

RFID systems differ greatly by the power and frequency in which the tags and reader operate. Some systems are only capable of reading tags one at a time as they pass on a conveyor-like system, while others can identify hundreds of tags within a shipping container as they exit a warehouse. The type of technology used varies greatly depending on the intended application, and no single technology is better than the other.

14.3 Current Alternatives

The primary alternative of RFID in industry is the very primitive means of labeling an object in words and having it read by a human. Increasingly barcodes and optical character recognition (OCR) have become widespread in big business. There are also emerging technologies that compete with RFID, such as Bluetooth which is currently used in some PDA and cellular phones and can identify and communicate with objects within a piconet.

Each identification technology has its drawbacks. Human readable labels lack automation; barcodes require line-of-sight and a compatible reader. OCR technology only offers the ability for a computer to read what a human can and requires very sophisticated technology. Bluetooth technology provides the ability to transfer a large amount of data and is superfluous for identification purposes (Allied Business Intelligence Inc. 2002).

Table 6 describes various types of transponder attributes, while Table 7 provides performance data at various frequencies.

Table 6. Transponder Characteristics of Various Types

(Allied Business Intelligence Inc. 2002)

Transponder Attribute	Performance Characteristics
Chip	The transponder contains an IC which provides the basic functionality of the transponder, including memory and anti-collision properties
Chipless	Chipless transponders do not contain an IC on the tag. Instead, these tags usually rely on reflected energy to produce a unique identification. While they lack many of the performance capabilities of a chip tag, they are far less expensive.
Passive	Passive tags do not require a battery for RF transmission. Generally, these tags are powered by the reader antenna through an antenna located on the tag. The reader's transmission is coupled to the specially designed antenna through induction or E-field capacitance which generates a small voltage potential. This power is then used by the IC to transmit a signal back to the reader or reflect back a modulated, encoded identification. Note that some passive tags do have a battery which is used for ancillary features, such as an LED or LCD display, not transmission.
Active	Active tags incorporate a battery to transmit a signal to a reader antenna. These tags either emit a signal at a predefined interval or transmit only when addressed by a reader. Either way, the battery provides the power for RF transmissions, not an inductive or capacitive coupling.
Read-only	Tags with read-only memory are pre-programmed at manufacture with a unique and/or randomly assigned identification code.
Write-once	These differ from read-only tags in that they allow the end-user to program the tags memory. Therefore, as an item progresses down a conveyor, for example, an end-user can encode a write-once tag with the item's serial number or part number which cannot be erased.
Read-Write	These allow for full read-write capability, allowing a user to update information stored in a tag as often as possible. Information updates can include a temperature log in more sophisticated tags or simple binary information such as whether or not an item passed an inspection.
Anti-Collision	Though there are many different approaches to anti-collision protocols, the goal is the same: to allow multiple tags to be read by a single reader simultaneously. Without anti-collision, multiple tags will interfere with each other preventing the reader from recognizing the tags.

Table 7. Transponder Performance at Various Transponder Frequencies

(Allied Business Intelligence Inc. 2002)

Frequency Range	LF 125 KHz	HF 13.56 MHz	UFH 868-915 MHz	Microwave 2.45 & 5.8 GHz
Typical Max Read Range (Passive Tags)	< 0.5 m	~1m	~3m	~1m
General Characteristics	Relatively expensive, even at high volumes. Low frequency requires a longer, more expensive copper antenna. Additionally, inductive tags are more expensive than a capacitative tag. Least susceptible to performance degradations from metal and liquids, though read range is very short.	Less expensive than inductive LF tags. Relatively short read range and slower data rates when compared to higher frequencies. Best suited for applications that do not require long range reading of multiple tags.	In large volumes, UHF tags have the potential for being cheaper than LF and HF tags due to recent advances in IC design. Offers good balance between range and performance - especially for reading multiple tags.	Similar characteristics to the UHF tag, but with faster read rates. A drawback to this band is that microwave transmissions are most susceptible to performance degradations due to metal and liquids, among other materials. Offers the most directional signal, ideal for certain applications.
Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitative coupling	Active tags with integral battery or passive tags using capacitative, E-field coupling	Active tags with integral battery or passive tags using capacitative, E-field coupling
Typical Applications Today	Access control, animal tracking, vehicle immobilizers, POS applications including SpeedPass	"Smart Cards", Item-level tracking including baggage handling (non-US), libraries	Pallet tracking, electronic toll collection, baggage handling (US)	SCM, electronic toll collections
Notes	Largest install base due to the mature nature of low frequency, inductive transponders	Currently the most widely available high frequency worldwide, due mainly to the relatively wide adoption of smart cards	Japan does not allow transmission in this band. Europe allows 868 MHz whereas the US permits operation at 915 MHz, but at higher power levels	
Data Rate	Slower			Faster
Ability to read near metal or wet surfaces	Better			Worse
Passive Tag Size	Larger			Smaller

15 RFID Applications

Table 8 describes various applications suitable for RFID deployment, along with competing technologies, current penetration level, and the typical type of RFID tag associated with the application.

Table 8. RFID Application Matrix

(Allied Business Intelligence Inc. 2002)

Application Segment	Representative Applications	Competitive Technologies	Current Penetration	Typical Tag Type
Access Control	Doorway Entry	Other keyless entry technologies	High	Passive
Asset Tracking	Locating tractors within a freight yard	None	Low	Active
Asset Tagging	Tracking corporate computer systems	Bar Code	Low	Passive
Authentication	Luxury goods counterfeit prevention	Holograms	Low	Passive
Baggage Tracking	Positive bag matching	Bar Code, Optical Character Recognition	Low	Passive
POS Applications	SpeedPass	Credit Cards, Debit Cards, Smart Cards, Wireless Phones	Medium	Passive
SCM (Container level)	Tracking containers in shipping terminals	GPS-based systems	Low	Active
SCM (Pallet level)	Tracking palletized shipments	Bar Code	Minimal	Active, Pallet
SCM (Item level)	Identifying individual items	Bar Code	Minimal	Passive
Vehicle Identification	Electronic toll collection	Bar Code, License plate reader systems	Medium	Active, Passive
Vehicle Immobilizers	Automotive ignition systems	Other theft prevention technologies	High	Passive

15.1 Suppliers

The transponder or tag is the most important part of an RFID system because it dictates the system's performance characteristics. Because of this fact it is important to understand the supplier industry.

Larger companies in the industry typically offer the largest range of products, from low to high frequency bands. These products are mature in the market and have sold millions to date. Philips and Texas Instruments are examples of some of these larger companies. Recently some smaller companies have sought to take advantage of emerging RF circuitry that have made tags affordable for the UHF and microwave bands. These small companies hope to capitalize on a potential popularization of these new bands. Older companies, however, have focused on refining the existing technology. As mentioned previously, the standards used by these smaller

companies working with new technology is under debate and a source of some controversy (Allied Business Intelligence 2002).

15.2 Standards

Standards for RFID have been slow to develop over the years. The International Standards Organization (ISO), the Uniform Code Council (UCC) and the Auto-ID centers at the Massachusetts Institute of Technology (MIT) and Cambridge University are among the parties developing standards.

The current standard most referenced for RFID is ISO 15693. The standard was developed for "contactless vicinity cars," however it is most often used for item-level tagging. Manufacturers have continued to use the standard in hopes to assure customers that their RFID technology will not quickly become obsolete. The new standard being developed for item-level tracking at 13.56 MHz is the ISO 18000 and will be backward compatible with ISO 15693

Beginning in 2002, the UCC and ISO agreed to focus their attention on developing standards for UHF tags used in supply-chain applications. Allied Business Intelligence believes this will facilitate the release of a final standard (Allied Business Intelligence Inc. 2002).

16 Active and Passive RFID

Active RFID and Passive RFID technologies are often combined as a whole when referring to RFID; however they are "fundamentally distinct technologies with substantially different capabilities." Effective supply chains do not rely solely on one particular technology, but use both active and passive technologies in complementary ways for complete visibility (Savi Technology 2002).

16.1 Definition of Active and Passive RFID

Both active and passive technologies utilize radio frequency energy to communicate between a tag and a reader. However the technologies differ by the means in which they are powered. Active RFID utilizes an internal power source (battery) for a continuous source of power. Alternatively, passive RFID utilizes radio frequency energy from the reader to obtain its power. Because passive RFID relies on a reader, a passive tag is only "on" when it is communicating with a reader.

Passive RFID is able to utilize energy from the reader in one of two ways. It either reflects the energy of the reader back to it, or it absorbs the energy of the reader and temporarily stores enough to generate a response. Because passive RFID lacks its own power, it requires a very strong signal from the reader and is not capable of producing a very strong transmission in return. Active RFID tags are able to operate on a relatively weak signal from the reader, because the tag has its own power source to respond. With a battery, active RFID tags receive continuous power that has tremendous implications with communication range, multi-tag

collection, and the ability to add sensors and data logging (Savi Technology 2002). Table 9 describes some of the differences between active and passive RFID technologies.

Table 9. Technical differences between Active and Passive RFID technologies (Savi Technology 2002)

	Active RFID	Passive RFID
Tag Power Source	Internal to tag	Energy transferred from the reader via RF
Tag Battery	Yes	No
Required Signal Strength from Reader to Tag	Continuous	Only within field of reader
Required Signal Strength from Reader to Tag	Very low	Very High (must power the tag)
Available Signal Strength from Tag to Reader	High	Very low

16.2 Functional Capabilities of Active and Passive RFID

Savi Technology (2002) identifies the follow factors that influence whether Active or Passive RFID should be implemented for a given application.

16.2.1 Communication Range

Passive RFID is typically limited to a range of 3 meters or less. In some instances, depending on the vendor and frequency of operation the range may be only a few centimeters. Passive RFID is limited by the factors mentioned above: reliance on a strong signal from the reader, and its inability to send a strong signal due to lack of a power source. Active RFID, due to its continuous power source can communicate at ranges of 100 meters or further.

16.2.2 Multi-Tag Collection

Due to the lack of communication range of Passive RFID, multi-tag collection is infeasible because the area encompassed by multiple products will exceed the range of the technology. In a situation where multiple tagged products are passing a reader's vicinity, multiple tags must be read quickly. Under either technology tags can, of course, be read one-at-a-time. However with Passive RFID it takes much longer to communicate with reduced RF energy and it is very difficult to read all of the tags before they move beyond the range of the reader. One passive reader, pervasive throughout industry, takes 3 seconds to read 20 tags, limited to a range of 3 meters. Therefore if 20 items are moving at a speed greater than 1 meter per second they cannot be read. Furthermore, if there are more than 20 items moving at 1 meter per second they will not be read. Due to the range and increased read speed, this is a non-issue with respect to Active RFID.

16.2.3 Sensor Capabilities

Growing focus has been placed on the implementation of sensor capabilities into RFID tags. Such capabilities include temperature, humidity, shock, security, and tamper protection. Since

Passive RFID tags do not receive continuous power (only within the range of a reader) they are unable to continuously monitor the status of the tagged product. Active RFID will be able to accomplish these applications; in addition, Active RFID can power an internal clock which can place a date and time stamp on each recorded sensor value or event.

16.2.4 Data Storage

Both Active and Passive RFID have the capability to read and write data within a tag. Due to power limitations, Passive RFID is capable of only about 128 bytes or less of read/write memory. Furthermore, Passive RFID has no search capabilities or data manipulation features. Therefore, for large data storage or sophisticated data access requiring the tag to be powered for extended periods of time, Passive RFID is not a viable choice. Active RFID tags are prevalent in industry with 128 kilobytes of read/write data with search and manipulation capabilities (Savi Technology 2002).

Table 10 overviews the functional capabilities of both types of RFID technologies.

Table 10. Summary of functional capabilities of Active and Passive RFID technologies (Savi Technology 2002)

	Active RFID	**Passive RFID**
Communication Range	Long range (100m or more)	Short or very short range (3m or less)
Multi-Tag Collection	-Collects 1000's of tags over a 7 acre region from a single region -Collects 20 tags moving at more than 100 mph	-Collects up to a few hundred tags within 3 meters from a single reader -Collects 20 tags moving at 3mph or slower
Sensor Capability	Ability to continuously monitor and record sensor input; data/time stamp for sensor events	Ability to read and transfer sensor values only when tag is powered by reader; no date/time stamp
Data Storage	Large read/write data storage (128KB) with sophisticated data search and access capabilities available	Small read/write data storage (e.g. 128 bytes)

17 Applications of Active and Passive RFID to Supply Chain Visibility

As mentioned previously, Active and Passive RFID each have their own applications to which they are best suited within the supply chain. Passive RFID is best suited for applications where the movement of materiel is a highly consistent and controlled environment, and where there is not a need for security or sophisticated data storage or manipulation. Active RFID is more appropriate where materiel flow is dynamic and unconstrained and where there is a need for enhanced security and data capabilities. Both technologies play important roles in achieving complete supply chain visibility. Savi Technology (2002) outlines some of the main tasks of supply chain visibilities and recommends which RFID technology for each.

17.1 Area Monitoring

Active RFID is the only practical technology for area monitoring. Due to the continuous nature of monitoring, only Active RFID has the power supply for such applications. Savi Technology (2002) provides the following instances of area monitoring: collecting real-time inventory information within a warehouse, monitoring the location of empty and loaded air cargo containers across an air terminal or tarmac, and monitoring the security of ocean containers or trailers stored in a yard or terminal.

17.2 Spot-Level Locating

One means in which RFID enables visibility is by automatically collecting data on materiel as they flow through processes. In order to accomplish this, readers must be precisely located at specific points within a process. Savi Technology (2002) provides the following examples of spot level location: (1) identifying the exact parking slot of vehicles in a truck yard, (2) identifying the specific storage rack of a pallet within a distribution center, and (3) identifying the specific loading bay in current use by an air cargo ULD.

A finely tunable short-range communication link is needed to identify materiel within a specific location and not those in surrounding areas. Passive RFID is best suited for this application, specifically the lower RF frequencies (134kHz and 13.56 MHz). Higher frequencies tend to lead to unwanted "cross reads" from surrounding areas.

Recently dual-range Active RFID products have been introduced that are capable of producing a tunable, short-range link in addition to its standard long-range link. This new technology offers several advantages over conventional Passive methods: the ability to use separate frequency bands for both short- and long-range links and the ability to provide area monitoring and other enhanced features exclusive to Active RFID.

17.3 High-Speed, Multi-Tag Portal Capability

Portals can consist of a variety of different species in a supply chain. A portal is any type of doorway, gate, or opening through which materiel flows. Examples may include dock doors at a distribution center, entry/exit gates at an intermodal terminal, and conveyor checkpoints in a parcel sorting operation.

In order for a reader to identify multiple tags flowing through a portal it must possess the ability to collect multiple tags at high speed, and differentiate between the tags within the specified portal area, and not those in surrounding areas. Large-scale application such as roadside monitoring is available only with Active RFID as only it has the necessary range. Passive RFID can handle small to medium size portals such as doorways and conveyor checkpoints, but lack range and can only read tags moving relatively slowly (5 to 10 mph or less). Dual-range Active RFID, as mentioned above, offers the most versatile means of identifying multiple tags through a portal. It is capable of reading tags at very high speed (>60mph) and can handle small, medium, and large-scale applications.

17.4 Cargo Security

RFID can offer cargo security through electronic seals. Both Active and Passive RFID have their place in security depending on the application and level of security needed. Passive RFID are only able to detect whether a seal has been broken. Due to their lack of a power source, Passive RFID tags are unable to continuously monitor the seal recording its status throughout the journey. Active RFID is, however, able to continuously monitor cargo and record the date and time of a potential breach and also employ sophisticated "anti-spoofing" techniques to prevent thieves from tricking the tag.

17.5 Electronic Manifest

For cargo containers containing a variety of materiel it may be necessary to store an electronic manifest within the tag itself. Active RFID is the only viable means to store such a large amount of data. However, Passive RFID may be used to transmit an EPC number that could point to a manifest on an external database.

In addition to the above listings of advantages of Active RFID, one overall advantage is the minimal impact it places on the overall supply chain process as compared to Passive RFID. Passive RFID will restrict and restrain materiel flow as it has a very small communication range. This could cause materiel movement systems (conveyors) to be altered to accommodate this. In addition Passive RFID has difficulty in multiple tag collection and would require that materiel be adequately spaced so that interference is minimized. Passive RFID may also slow down the materiel movement process as it can only read tags at relatively low speeds. The low cost of Passive Tags must be compared with the potential savings of Active RFID in the supply chain.

Table 11 describes the applicability of active and passive RFID technologies to improved/enhanced supply chain visibility.

Table 11. Applicability of Active and Passive RFID technologies to supply chain visibility (Savi Technology 2002)

	Active RFID	**Passive RFID**
Area Monitoring (e.g. warehouse, terminal, yard)	**Yes**	**No**
Spot-Level Locating	**Yes** (with dual-range active)	**Yes** (13.56MHz and lower frequencies provide best performance)
High-Speed, Multi-tag Portal	**Yes** (hundreds of tags, 60+ mph) (Smaller portals require dual-range active)	**Limited** (<5-10 tags, <3-10 mph)
Cargo Security Applications	Sophisticated (continuous tamper detection, anti-spoofing techniques, date/time stamp)	**Simple** (one-time tamper event detection, no time stamp, susceptible to "spoofing")
Electronic Manifest	**Yes**	**No**
Business Process Impacts	**Minimal**	**Substantial**
Application Characteristics	▪ Dynamic business process ▪ Unconstrained asset movement ▪ Security / sensing ▪ Data storage / logging	▪ Rigid business process ▪ Constrained asset movement ▪ Very simple security / sensing ▪ Limited data storage

17.6 Complementary Use of Active and Passive RFID

The following two examples are excerpts from a Savi Technology (2002) white paper that demonstrate the appropriate pairing of both Active and Passive RFID technologies.

17.6.1 Example #1: Air Cargo

In a typical air cargo operation, boxes and items are consolidated into Unit Load Devices (ULDs), which in turn are loaded into the belly of an aircraft. The boxes and items only need to be separately tracked up to the point at which they are loaded into the ULD. Once loaded and manifested, the location and status of the items can be determined by tracking the associated ULD. Since the loading process is usually structured and orderly, with dedicated loading stations and conveyors, Passive RFID is often sufficient and most cost-effective for tracking the individual items and boxes (Table 12). The ULDs, however, present different tracking requirements. They move throughout large air terminals and tarmac areas, requiring area-monitoring capabilities to locate specific ULDs for loading onto the aircraft. There are also significant security concerns, driving requirements for sophisticated sealing and security monitoring capabilities as loaded and empty ULDs are moved throughout the airport facility and

loaded onto aircraft. All of these requirements lead to the need for Active RFID technology for the ULD.

Table 12. Typical RFID requirements for Air Cargo

Item	Characteristics	Technology
Boxes **Individual Items** **Luggage**	-Structured, orderly process for loading – dedicated loading stations, conveyors	Passive RFID, Bar code
ULD **(Unit Load Device)**	-unstructured movement throughout airport facility (unstructured) -security requirements	Active RFID

17.6.2 Example #2: Intermodal Cargo

Similar to air cargo, intermodal cargo shipments typically have a hierarchical structure of items within containers. A common hierarchy includes boxes and cartons loaded on pallets, pallets loaded into intermodal containers, and intermodal containers loaded on chassis, rail cars, and ships. The pallets are often loaded with boxes, cartons, and other items as part of an orderly build-up process within a factory or warehouse, making Passive RFID an appropriate fit in many situations (Table 13). Once loaded, tracking of the pallets may require either Passive or Active RFID, depending on the particular situation. In some cases, pallets move through dedicated portals or dock doors, one or two at a time, and there is no need to monitor their location and status at other times. In other cases, the movement of pallets is more dynamic, within open yards and facilities, and there may be a need to continuously monitor their presence, not just at dock doors or other specific read points. Passive RFID is appropriate for the former, Active RFID for the latter.

At the intermodal container level, security is once again a concern, especially as the US and other countries push cargo inspections back to the point of origin and require highly reliable validation of the container integrity at the destination. There may also be the need for roadside monitoring of container movement, and for continuous monitoring of containers within ports, terminals, and other large facilities. Active RFID, therefore, is the right selection at the container level. For chassis, rail cars, ships, and other conveyances, the appropriate technology may be Active RFID or a combination of Active RFID with GPS-enabled wide-area monitoring. With this latter combination, the ability to track in-transit container movements (via GPS) can be combined with continuous monitoring of an Active RFID security seal on the container, providing a highly reliable cargo monitoring and security solution.

Table 13. Typical RFID Requirements for Intermodal Cargo

Item	Characteristics	Technology
Boxes Cartons Individual Items	-structured, orderly process for loading – dedicated loading stations, conveyors	Passive RFID Bar code
Pallet	-structured or unstructured movement, depending on situation	Passive RFID or Active RFID
Intermodal Container	-security requirements -area monitoring within ports, terminals -roadside monitoring	Active RFID
Chassis, rail car, other conveyance	-area monitoring within ports, terminals -roadside monitoring -in transit visibility	Active RFID GPS (wide area)

Transceivers are strategically placed to interrogate tags where their data is required. For example, an RFID access control system locates its tag readers at the entry points to the secure area. The transceivers continually emit an interrogation signal, which forms an interrogation zone within which the transponders may be read. The actual size of the interrogation zone is a function of the transceiver and transponder characteristics. In general, the greater the interrogation signal power and the higher the interrogation signal frequency, the larger the interrogation zone. Sending power to the transponders is usually the bottleneck in achieving large read range with passive tags. Active tags do not suffer from this drawback and therefore typically have larger read rangers than an otherwise equivalent passive tag.

18 Disadvantages of Barcodes

Barcodes are cheap, reliable, and easy to implement, however they have several disadvantages. Barcodes are only capable of identifying classes of products, not the individual item itself. This is limited by the amount of data the barcode can store. Tags, however, when used in conjunction with a digital numbering scheme such as an EPC, have the ability to identify every single manufactured item on the planet. Barcodes require a line of sight between the reader and the barcode whereas tags only need to be within the specified range of the reader. This allows tags to be read efficiently in large quantities.

Barcodes become useless if the label itself is damaged, however tags are often built into the product itself which provides protection in addition to its already robust design capable of withstanding various chemical and heat environments that would render barcodes useless. Barcodes are also static and cannot be updated without physically printing a new label. Tags are dynamic in that data can be read and written to a tag an infinite number of times. Furthermore, as mentioned earlier, tags can store a much larger amount of data than what is offered with traditional barcodes (Agarwal 2001).

Alexander *et al.* (2002a) present Tables 14 through 16 on Auto-ID.

Table 14. Auto-ID opportunities and benefits by time horizon

High

Opportunities & Benefits

Low

Pallet Tagging
-Product diversion
-Supplier VMI/replenishment
-Production planning
-DC/Goods receipt
-Put-away
-Inventory control and storage
-Real-time ATP inventory

Case Tagging
-Case theft
-Retail OOS
-Demand planning
-Supply planning
-Subcontracting/re-packer visibility
-Pick, Pack, & Ship
-Physical counts & reconciliation
-Cycle counts
-Consign/Hold inventory

Item Tagging
-Store level promotions and pricing
-Unit/item theft
-Pay-on-scan
-Consumer understanding
-Product R&D
-WIP inventory
-Routing
-Assembly
-Aging/Quality control
-MRP
-Capacity Planning
-Product assortments
-Product recall/warranty process

6 months — Time — + 5 years

Table 15. Auto-ID cost estimates for tags and readers

	2002	2003	2004	2005	2006
Industry tag sales (millions of units)	200	300	700	3,000	15,000
Tag price to highest volume users	0.40	0.30	0.20	0.10	0.05
Industry reader sales (millions units)	0.1	0.2	0.5	1	2
Reader electronic price to volume users	\$500	\$250	\$150	\$100	\$70

Table 16. Auto-ID in the Distribution Center

Coverage Area	How it Works	Benefits	Results
1. Receiving	-Reads pallet-level and case-level tags as product is moved off the truck and into the receiving area -Verifies match between pallet ID tag and cases on pallet, and source of product and purchase order – confirms receipt	-Eliminates manual steps to enable faster and more accurate receiving process	-Less labor -Better information accuracy -Improved throughput -Higher asset utilization -Reduces returns/claims -Improves customer service levels
2. Forklift / Order Picker	-Reads case tags as product is taken from location and placed on a pallet or belt (case picking) -Integrates with WMS and conveyor control to divert product record and transaction	-Eliminates manual steps to count and record picks -Eliminates time spent correcting errors -Improves order line fill rate	
3. Conveyor	-Reads case tags as product passes reader on belt -Integrates with WMS and conveyor control to divert product and record transaction	-Does not require line of sight -Eliminates time spent correcting no reads	
4. Shipping	-Reads pallet-level and case-level tags as product is moved onto the truck -Integrate with the WMS to confirm product, customer, truck, load sequence	-Eliminates manual steps to enable faster and more accurate loading -Enables direct loading from pick	

19 Reader Collision Problem

The reader collision problem is the "problem of allocating frequencies over time to RFID tag readers such that their interference with one another is minimized." In complex RFID systems, containing multiple readers, it is possible that the readers may interfere with each other; this interference is referred to as a "reader collision." These collisions will prevent the readers from interfacing with tags in the vicinity. It is important that collisions be minimized in order to ensure continuous and accurate communication between readers and tags. There are several centralized global graph-based formulations and variants of the reader collision problem as well as several on-line algorithms to solve it. The only downside to these algorithms is they significantly increase the time it takes to read a tag (Engels 2001).

20 Industry Applications

Vendor Managed Inventory (VMI): The most commonly cited example of VMI is Wal-Mart and Proctor & Gamble (P&G). P&G have visibility into Wal-Mart's in-store stock levels of Pampers diapers. P&G manage the stock replenishment process for Wal-Mart.

The Gap, Wal-Mart, Revlon, Proctor & Gamble, and McDonald's are among the leading retailers and consumer goods manufacturers currently conducting RFID trials (Burnell 2001).

20.1 ABF

ABF Freight, a $1 billion motor carrier, based out of Fort Smith, Arkansas implements Nextel's wireless technology to increase visibility. ABF uses Nextel's micro-browsers which are cellular phones that have open connections to the Internet. Wes Kemp, vice president of terminal operations for ABF, says there are two main reasons for choosing Nextel micro-browsers, "The first is visibility of freight for our customers. The second is control . . . This particular technology is very cost-effective. With our micro-browsers, data goes from the driver to the Internet to our mainframe." Kemp goes on to say that, "There are a number of proprietary systems that have some bells and whistles that micro-browsers don't have . . . We don't get everything those onboard computers have, but we get about 80% of it for a fraction of the cost."

ABF's technology is based on a mass-produced cellular phone that costs approximately $80. The technology is deployed in three main areas: street, dock, and yard. Kemp says, "Before the drivers get back to the terminals, management knows what's coming in. . . Consequently, they can better plan their loads." Under street operations drivers enter data on the cellular phone's keypad such as piece count, destination zip code, and the PRO number. The data is then immediately transmitted to ABF's mainframe computer. Once all of the pickups have been logged, a manager can formulate a delivery plan. For delivery, drivers can use the micro-browsers to log a delivery once it has been made rather than waiting for the driver to return to the terminal. This allows customers to be notified in real-time on the Internet when the delivery has been made. On the dock's, workers can reference micro-browsers to tell them which door the shipment should be loaded/unloaded based on a PRO number (Hyland 2002).

20.2 Nextel

Nextel's product line begins with a cellular system that allows for two-way communication similar to the above situation with ABF. A step up from this system is Direct Connect, a technology that allows radio communication similar to a Walkie Talkie but does not require a cellular call to be made. Nextel then offers two-way text messages which are sent to hand-held devices through the Internet and Nextel's network. Nextel also offers a product line with much more sophisticated features, such as individual package tracking, signature capture, proof of delivery, shipment tracking, and route optimization. These solutions require partnership agreements with various vendors. One such partnership is with @Road, a provider of fleet management solutions with an in-vehicle Global Positional Satellite (GPS) unit. Vehicles can then be tracked in real-time via handheld devices (Hyland 2002).

21 Software

21.1 WhereSoft

WhereNet Inc. offers its WhereSoft Visibility Software Suite (VSS) that allows companies to track each element in their supply chain. The solution consists of wireless tags, fixed-position antennas, location processors, and other software that allows a company to track the location of any tagged object to within ten feet. The VSS platform is based on the standard RFID interface. Location processors attached to a company's local area network (LAN) will process the data which is then transferred to a Windows NT server running SQL server 7.0 database. The server can be setup to interface with other applications such as a container management application that would allow tracking of parts shipped in containers or other storage devices. The price tag for VSS ranges from $100,000 to more than $1 million depending on the size and complexity of the supply chain.

21.2 i2 Transportation Management System

The i2 Transportation Management System (TMS) is part of the i2 Supply Chain Management solution suite.

- Uses three-dimensional analysis to build loads that honor all operational and physical constraints
- Leverages sophisticated solving techniques to create optimized shipment plans
- Enables proactive monitoring and intelligent exception management that provides visibility across shippers, carriers, vendors, and customers.
- Creates sustainable value by synchronizing all critical transportation execution processes that result in optimal cost and service performance (www.i2.com 2002)

21.3 i2 Inventory Visibility Service

"i2 Inventory Visibility Service is an execution and decision support solution that helps an organization and its trading partners make accurate and timely replenishment decisions. Inventory Visibility Service enables collaborative business processes such as vendor managed inventory (VMI) and supplier managed inventory (SMI)."

- Gain inventory visibility into the true state of the supply chain by representing the various stocking locations (buffers) in multiple tiers
- Intuitive graphical user interface that provides rapid exception detection
- View and edit data across multiple buffers in one screen
- Filtering and sorting capabilities on key screens and reports
- Define user preferences to control and settings of views (www.i2.com 2002)

Table 17 presents Forrester Research's ratings on the strengths and weaknesses of various logistics management vendors.

Table 17. Forrester Research Rates the Strengths and Weaknesses of Adaptive Logistic Management (ALM) App Vendors (Kilgore 2002)

App vendor	These vendors have strong . . .	These offerings and strategies lack . . .
Celarix	Active network, personalization, partners	Adaptive resolution, static inventory
Descartes	Active network, shipment tracking, customer base	Usability, adaptive resolution, exception management
Elogex	Shipment management	Order, static inventory resolution
Escalate	Installed base, retail and order focus	Adaptive resolution, personalization
Exemplary	Practitioner exec team, trend analysis	Shipment management, client installs
G-Log	Global-shipment resolution	Order, static inventory support
i2	Order notification, tracking, partners	Adaptive resolution, company focus
IMI	Order and data management	Shipment support, multi-application resolution
Manhattan Associates	Adaptive execution and technology strategy, financial viability	Current monitoring and even management capability
Manugistics	Partnerships, operational reporting	Adaptive execution, object monitoring
Optum	Service chain focus, community management, static inventory support	Watch lists, self-learning, channel and partner strategy
Saltare	Pattern detection, trend analysis	Guided resolution, usability, client base
Schneider Logistics	Global network, shipment tracking, financial stability	User personalization, adaptive execution
Valdero	What-if analyzer, corrective resolution	Process synchronization, active network
Viewlocity	Usability, inventory process flexibility, momentum, adaptive resolution	What-if analyzer, self-learning, channel strategy
Vigilance	Event tracking, escalation, resolution	Monitoring, optimization capability
WorldChain	Practitioner exec team, integration ease, guided resolution	Self-learning, shipment support, reporting
Yantra	Dynamic order management, supplier management, customer base	Shipment support, automatic exception resolution

Milestone D - Recommendation of Commercial TAV Practices

For the Air Force to attain total asset visibility it will take years to set up the necessary infrastructure. A consolidated database receiving real-time information from RFID technology is recommended throughout the Air Force in order to achieve this goal.

The following section gives an overview of implementation of the technology detailed above. Explicit detail is not given in this section as the details of implementation are given in the technology section.

22 Deciding on Standards

There are several initial steps the Air Force and military in general must undertake in order to embark upon the challenge of total asset visibility. This first is choosing standards. Standards must be chosen on several levels, from what RFID frequencies to use, to what "serial number" methodology to use in identifying products, to what type of database and computer platform to use for their consolidated database. The Air Force is a large enough entity such that they could form their own standard or the military could form their own standard separate from commercial industry. The Air Force, and military in general, use a lot of proprietary products and have their own infrastructure such that, for the most part, general purpose, commercial goods, do not flow in the Air Force supply chain. With this in mind, separate Air Force standards would not create a large problem because their supply chain is a closed system. In the sections that follow recommendations will be given as to which standards to choose for each visibility agent.

23 Codes and Languages

It is recommended that the Air Force adopt the Auto-ID center's Electronic Product Code (EPC) for identifying individual items. This 128-bit code has the capacity to handle each individual item of Air Force materiel and not just classes or types of items. The EPC code would allow the Air Force to track a particular part for a particular plane throughout its life and log its use and repair history. The EPC code would not replace the current National Stock Numbering (NSN) System implemented by the Air Force. The NSN would still be needed to identify classes and types of products. An EPC should be automatically generated by the database for every individual item the Air Force wishes to track or monitor.

It is also recommended that the Air Force adopt the Product Markup Language (PML) of the Auto-ID center. PML is the link between the EPC and the Object Naming Service (ONS). PML is the method for describing physical objects to the Internet.

The ONS, mentioned above, should also be adopted in order to complete the infrastructure proposed by the Auto-ID center. The ONS should be incorporated into the Air Force's database system. The ONS should be setup the same way a Domain Name Server (DNS) is set up on the

Internet. It should be a database that every computer can communicate with in order to translate an EPC into the object name that is requested.

24 Databases

The Air Force should phase out all of its subsidiary databases that serve various niches of the Air Force and replace them with a single, all-purpose database that all users can access from anywhere in the world. Meeting this second requirement suggests that the database should be web-based and have the capability of tracking all types of assets.

The JTAV initiative suggests a common database that is fed data at predetermined intervals from one of the many subsidiary databases that currently exist. It would prove much more efficient if the primary database was developed with the capability to perform all Air Force supply chain tasks such that personnel at the root of the chain can use it to enter data and retrieve information. Under the current initiative, the burden would still be on the user of the supply chain to choose which system to update based on the particular piece of materiel. Furthermore, none of the existing databases currently have the capability of tracking individual parts, only classes or types of items. The Air Force should have a single database that may be accessed by any user via the Internet. This would eliminate the need to have specialized terminals with dedicated communication lines such as those required by the SBSS system or special software as required by MASS. The user would only need a PC with an Internet connection that would connect personnel directly with the master database located on a remote computer. Users, through an Internet connection should have access to database information and be able to update the information contained in the database.

This database would necessitate an extraordinary amount of data storage. Capacity would be measured in terabytes not gigabytes. This database would have to accommodate the specifications and history log of every individual item the Air Force possesses.

The database should be located on a secure server with substantial firewall protection. Access to the database should be allowed only with a user ID and a password. Different levels of security should be allotted to Air Force personnel based on what information that particular person needs to access.

25 Technology—RFID

RFID combined with an effective database system will give the Air Force complete visibility into its supply chain. The Air Force will have the ability to locate materiel anywhere in the world in real time. It is recommended that the Air Force adopt RFID tags and readers throughout the supply chain that interface with the database system detailed above.

In order for RFID to be implemented all materiel must be tagged. This is best accomplished by the manufacturer, in the production stage, so that the tag is internal and protected from damage and tampering. The Air Force will need to embark upon a program that gets manufacturers of Air Force products to tag their parts and products in the manufacturing stage. This will be a

difficult task since tagging parts will require retooling, and in some cases require redesigning the part itself. All parts of assemblies and aggregates must be tagged. For example, if Lockheed Martin delivers an F-16 to the Air Force, every part of the F-16 must be tagged. This, of course, only needs to be done with parts that need to be explicitly tracked. It is not necessary to tag bolts, screws, washers, etc.

The Air Force should begin its tagging program at the pallet or container level and work down from there to case tagging and eventually item tagging. Item tagging will offer the most benefit to the Air Force, but of course is the most difficult to implement. Implementation tagging in phasing will allow the Air Force to gradually adjust to automatic identification and RFID technology. This will also greatly reduce the number of readers that initially need to be installed in the Air Force supply chain infrastructure.

Readers will have to be distributed throughout the Air Force supply chain and anywhere tags will need to be read. Readers will need to be installed at all warehouse and depot areas. For the monitoring of aircraft, readers should also be placed on the flight line for spot-level locating of specific aircraft.

The two main choices in RFID are whether to implement active or passive technology and what frequency(s) to select.

25.1 Frequency

Due to the high variability of environments and conditions in which RFID tags will be read, it is recommended that the Air Force use multi-band readers. The Air Force has assets on the water, in the desert, in the air, and in warehouses. These environments will necessitate a versatile reader capable of operating in all of these environments. Following the recommendations of the Auto-ID center, the reader should have capabilities of reading both high frequency (HF) (13.56 MHz) and ultra high frequency (UFH) (915 MHz) frequency bands. Each band will provide benefits for specific applications and it important to have the versatility to switch between the two. Specifically where each frequency should be used is detailed above.

High frequency bands are less expensive than inductive low frequency tags and are generally passive in nature. They have a short read range and are best suited for applications that do not require multiple tag reads. This is also currently the most widely available frequency world wide.

Ultra high frequency tags, when purchased in high volumes as the Air Force would, can be cost effective over LF and even HF tags. Their high performance and range are well-suited for multiple tag reading applications. This frequency is for use with active tags or passive tags, but the performance comes with active tag applications. The draw back to this frequency is that Japan does not allow this transmission on this band.

25.2 Active versus Passive RFID

Both active and passive technologies have their place within the Air Force supply chain. Specific instances of when active and passive RFID should be used are detailed above; an

overview is given below. Active RFID should be implemented for the most part, but there are specific areas where passive RFID may be used to reduce cost. Active RFID should be used for area monitoring applications such as obtaining real-time inventory information in a warehouse, monitoring the location of empty and loaded air cargo containers, and monitoring the security of stored containers. RFID should also be used in spot-level locating applications such as determining the exact parking location of aircraft, locating the specific storage rack of a pallet or container within a distribution center, or identifying the specific loading bay in current use.

Passive RFID should be used for locating specific objects is a small area such that the surrounding areas are not also scanned. Passive RFID operating at 13.56 MHz would work best, also eliminating unwanted "cross reads" that can occur with higher frequencies. Anytime multiple tags that need to be read such as multiple pallets, containers, or objects moving through a port, active RFID should be used. Whenever security or tampering is an issue for materiel located within a container, Active RFID should be with electronic seals. Passive RFID can be used on low-level security items where it is only necessary to determine if a container has been opened or not, and no further information is necessary. For higher-level security items, active RFID should be used to log the time that the seal was tampered with. Active RFID also offers sophisticated "anti-spoofing" technology to prevent the tag from being tricked.

Electronic manifests will be very important in deployment situations. As mentioned above, a huge problem in Operation Desert Storm was the lack of visibility into Air Force containers. With an electronic manifest detailing every element of materiel inside, the contents can automatically be updated and checked into a database. Only active RFID offers electronic manifest capabilities built into the tag. As mentioned earlier passive tags are capable of pointing to an electronic manifest located on an external database.

25.3 RFID Alternatives

Constraints exist when using radio frequency technology in the presence of munitions. For this reason it is recommended that global positioning satellite (GPS) tags be used to track munitions. Not only does this eliminate radio waves around explosive ordinates, it also provides constant, real-time tracking of munitions anywhere in the world. This is especially useful given the importance of extra security precautions needed in storing and transporting munitions.

26 Wal-Mart as a Model

Wal-Mart is always on the forefront of emerging technology, and due to its dominating position in the market, has the ability to enforce any implementations it wishes to impose. In June of 2003 Wal-Mart set the date of January 2005 for RFID implementation (Murphy and Hayes 2003). This means that 100 key suppliers will have to work with Wal-Mart using RFID to track pallets of goods throughout its supply chain. With this deadline in place there are still many issues to consider, primarily the shortcomings of the current technology and the cost of purchasing RFID tags and readers.

Linda Dillman, Wal-Mart's CIO outlined a timeline for RFID implementation. This quarter the scope of the pallet initiative will be defined, with detailed specifications emerging in the third and fourth quarter of 2003. RFID will then be tested through 2004 and go online with 100 of its largest suppliers in 2005. Dillman states that "At some point, like any other technology, like EDI, it'll be a requirement for doing business with Wal-Mart." The Air Force, like Wal-Mart has the force in the market place to make these kinds of demands on its suppliers.

Proctor and Gamble Co. has been experimenting with RFID for more than six months, holding pilot programs with Ahold USA, Target, Wal-Mart, and European retailer Metro. P&G CIO Steve David says Wal-Mart's impending deadline will speed adoption of the emerging technology (Murphy and Hayes 2003).

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